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Ambient Hydrocarbon and Ozone Concentrations Near a Refinery, Benicia, California, 1975

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Benicia, California
1975

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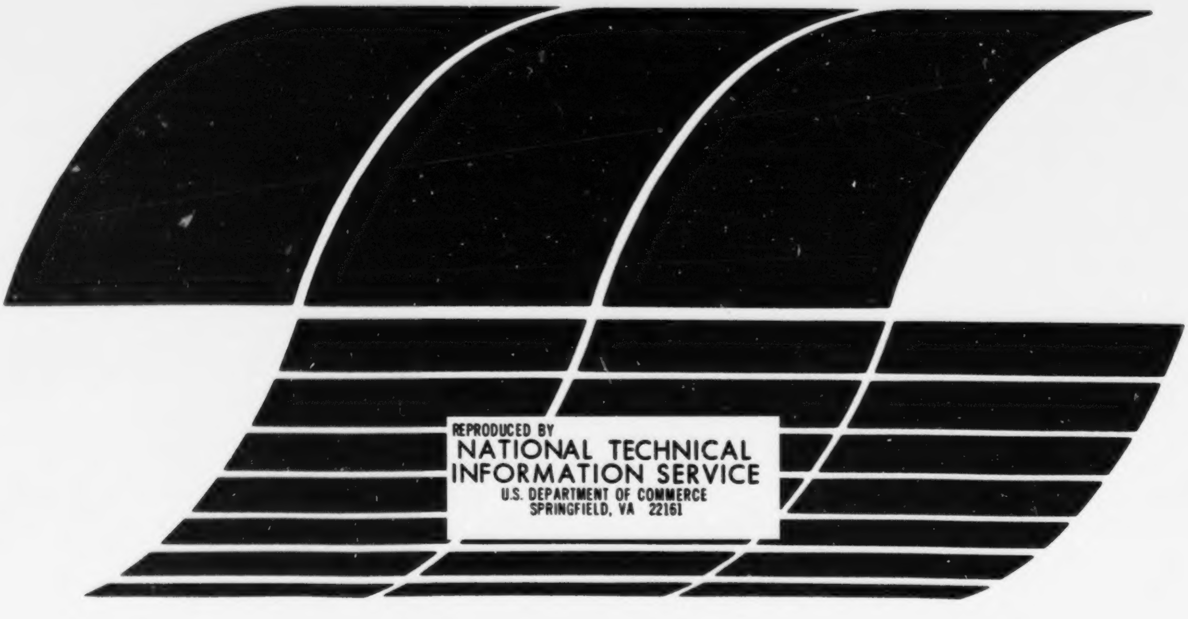

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As part of an effort to characterize airborne emissions from petroleum refineries, an ambient air monitoring study was conducted near the Exxon refinery at Benicia, California, during September 8-22, 1975. Ground-level sampling facilities and an airplane equipped with air pollutant monitoring instruments provided an integrated, three dimensional monitoring network. Measurements included ozone, oxides of nitrogen, methane, carbon monoxide, individual C_2 - C_6 hydrocarbons, halocarbons, condensation. Increased concentrations of hydrocarbons, carbon monoxide, condensation nuclei and nitrogen oxides, as well as decreased ozone levels were observed less than five miles from the refinery. At distances greater than 5 miles, elevated condensation nuclei and hydrocarbons were still observed but no discernible differences from background could be detected in NO_x, O_3, and CO. High ozone levels, greater than 100 ppb, were observed in the river delta region downwind of the refinery east of Antioch. However, all the available data suggest that the ozone buildup is a result of emissions upwind along the heavily industrialized area between Richmond and Antioch. The Exxon refinery could not be singled out as contributing significantly to the ozone buildup.

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Benicia, California 1975

by

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ABSTRACT

As part of an effort to characterize airborne emissions from petroleum refineries, an ambient air monitoring study was conducted near the Exxon refinery at Benicia, California during September 8-22, 1975. Ground-level sampling facilities and an airplane equipped with air pollutant monitoring instruments provided an integrated, three-dimensional monitoring network. Measurements made during the study included ozone, oxides of nitrogen, methane, carbon monoxide, individual C_2 - C_6 hydrocarbons, halocarbons, condensation nuclei, visual distance and various meteorological parameters. Particular emphasis was placed on determining hydrocarbon and ozone concentrations downwind of the refinery complex. The study focused on three major areas: (1) the characterization of gaseous components within the refinery effluent, especially non-methane hydrocarbons and ozone, (2) natural sunlight bag irradiation experiments to determine the ozone forming potential of refinery emissions, and (3) an investigation of changes in plume chemistry as refinery emissions were transported downwind.

This report was submitted in fulfillment of contract # 68-02-2239 by Washington State University under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from July, 1975 to June, 1976, and work was completed as of June, 1976.

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SECTION 1

INTRODUCTION

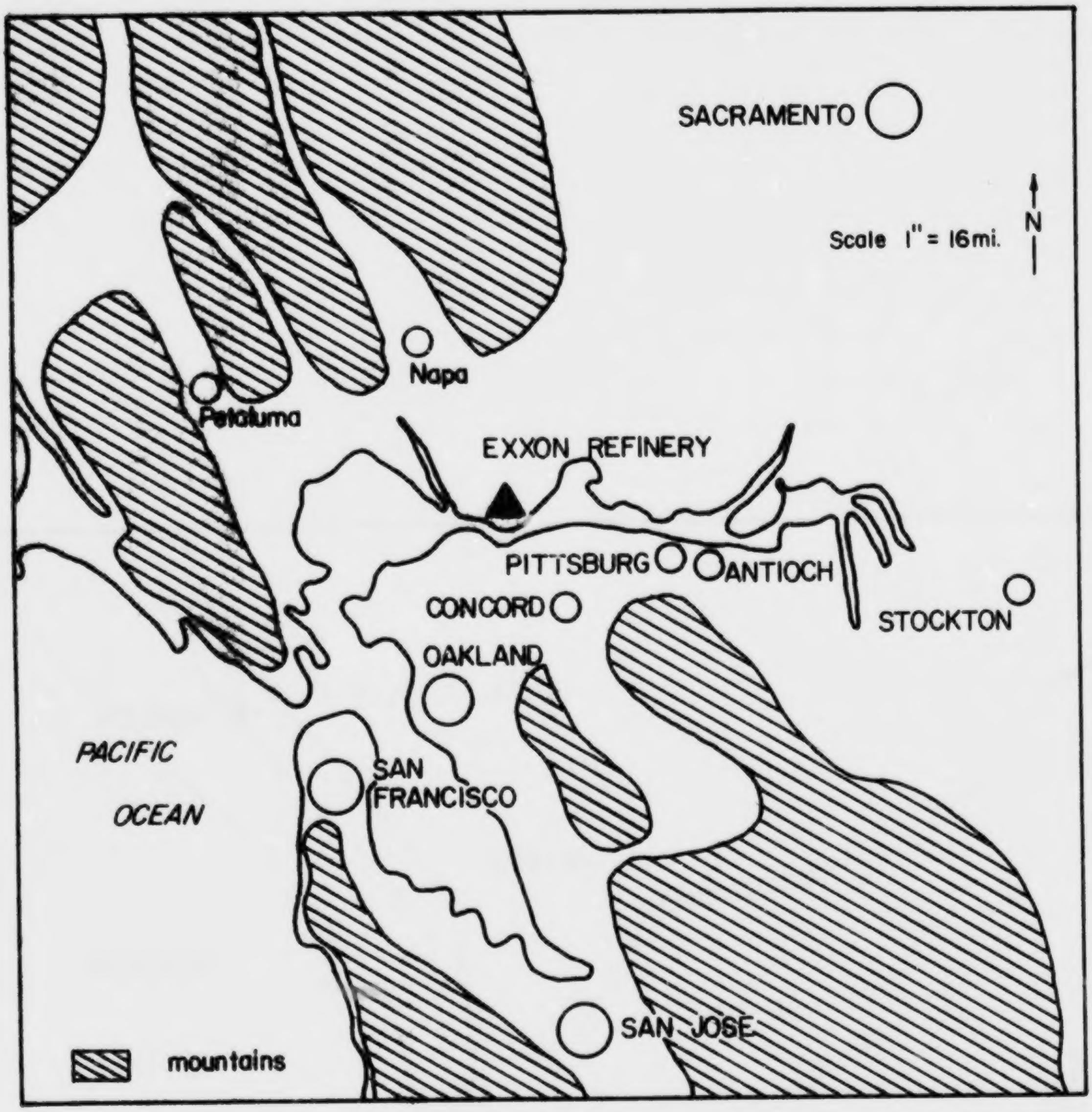
Modern petroleum refineries are large, complex facilities designed to convert crude oil into marketable products through a sequential series of unit operations. Atmospheric pollutants commonly result as by-products from virtually all refinery processing and may be emitted from such diverse sources as valves, pipeline joints, catalyst regenerators, and storage tanks. Considerable variation exists between individual refineries with respect to the types and quantities of contaminants released to the atmosphere. Such factors as crude oil capacity, processing scheme, and installed pollution control devices account for most of this variability. Along with malodorous and visible emissions, airborne discharges typically associated with petroleum refineries include hydrocarbons, carbon monoxide, oxides of sulfur and oxides of nitrogen.

Although refining operations are recognized as a significant source of certain primary pollutants, there is a paucity of data available to delineate the effect of refinery emissions on air quality. The absence of up-to-date emission estimates and the lack of ambient air measurements in the vicinity of oil refineries seriously hinders attempts to establish emission effects on downwind impact areas. In recent years, concern has been voiced about the possibility of photochemical ozone production within the refinery plume, but no published data are currently available to define the contribution of refinery emissions to observed downwind ozone buildup. As a result, current control strategies suffer from a critical lack of knowledge in this area.

Perhaps the most serious air pollution problem potentially attributable to refinery operations is the formation of photochemical oxidants within the plume during transport. The hydrocarbon-NO_x-UV light mechanism for the formation of ozone has been demonstrated in smog chambers[1-3] and shown in real air[4]. Because typical refinery emissions contain significant quantities of hydrocarbons and lesser amounts of NO_x, the possibility exists for oxidant formation under favorable conditions. Several studies have documented ozone transport from urban areas[5-7] and industrial point sources,[8,9] and investigators have recently observed ozone buildup downwind of petrochemical complexes.[10-11] However, few attempts have been made to quantify the contribution from a single petroleum refinery.

In 1974 Washington State University initiated a research program aimed at providing ambient air measurements near selected petroleum refineries. The project focused on characterizing typical emissions and investigating chemical transformations in the plume during transport. The first refinery study was conducted near the relatively isolated Texaco plant in Lawrenceville, Illinois.[12] The rural nature of the site and corresponding low background pollutant levels permitted easy identification and tracking of the refinery effluent. Results from the monitoring program revealed elevated concentrations of non-methane total hydrocarbons (NMTHC), oxides of nitrogen (NO_x), and carbon monoxide (CO) within the definable portion of the plume. Elevated hydrocarbon levels were observed out to 25 miles from the refinery, but no evidence of plume associated ozone production was found.

In order to investigate the possibility that enhanced ambient background pollutant levels (specifically NO_x) near urban and industrial centers might have an effect on plume chemistry, the Exxon refinery at Benicia, California was chosen as the site for additional study during 1975. Located approximately 25 miles northeast of San Francisco, the Exxon plant is in the midst of the heavily industrialized region extending from Richmond to Antioch. (See Figure 1). An instrumented trailer positioned 1.5 miles to the east of the refinery (see Figure 2) and an instrumented aircraft were used to provide an integrated, 3-dimensional sampling network. The field monitoring program was conducted during September 8-22, 1975.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PITTSBURG
ANTIOCH
CONCORD
STOCKTON
OAKLAND
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OCEAN
SAN FRANCISCO
SAN JOSE
▨ mountains

Figure 1. Map showing the location of the Exxon refinery and the general San Francisco Bay Area.

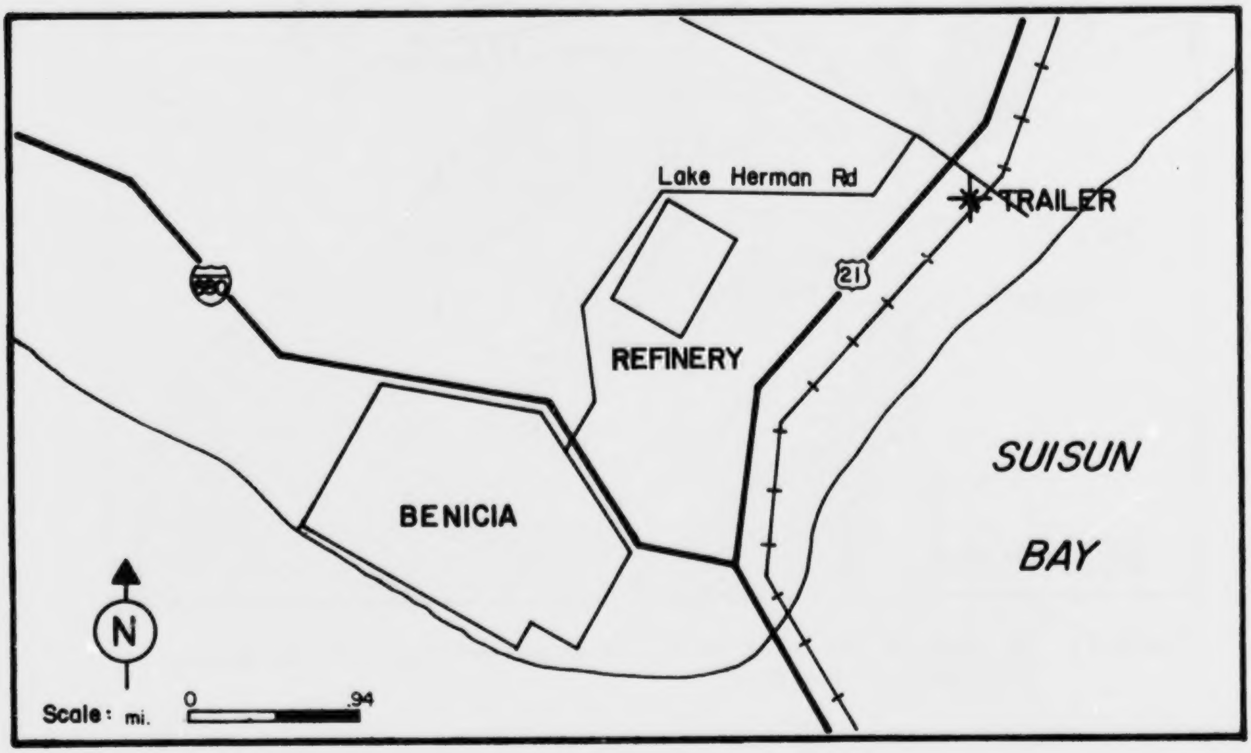
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Figure 2. Map depicting the location of the WSU instrumented trailer in relation to Benicia and the Exxon refinery.

SITE DESCRIPTION - CLIMATE

The summer climate of the Bay Area is determined primarily by the strength and position of the Pacific Subtropical High. Under normal conditions when the anticyclone is situated in the northern Pacific, relatively clean polar maritime air reaches the San Francisco Bay Area from the northwest. This air mass is typically characterized by low temperatures at the surface and a persistent temperature inversion at about 900 mb. This inversion is produced dynamically by subsidence in the eastern portion of the anticyclone and thermally by passage over cold upwelling water near the coast. In instances where the High extends over the continent, air moves into the Bay Area from the north or northeast. Because the anticyclone is seldom centered sufficiently far south to allow cyclonic storms to reach the region, precipitation in the Bay Area during summer months is usually light.

Boundary layer winds within the San Francisco Bay Area for summer months are influenced by monsoon-type conditions. High inland temperatures over the Central Valley and cooler temperatures along the coast create a pressure differential that generates strong eastward-flowing winds. The marine air is channeled as it moves inland by gaps in the coastal mountains, and the persistent low level subsidence inversion. Because the Bay Area provides the only sea level entrance into the Central Valley, via the Golden Gate - San Pablo Bay - Carquinez Strait - Suisun Bay channel, it is the most important passageway into the interior for cooler marine air.

Surface winds along the channel are normally from the west during the summer with speeds varying from 10-40 miles per hour. Because of these typically high wind velocities large quantities of energy are required to overcome the horizontal barrier formed by the almost constant temperature inversion. For this reason, little mixing occurs between the layers above and below the persistent temperature discontinuity. Further inland the inversion weakens or disappears altogether and wind speeds decrease drastically.

Measurements at the WSU trailer site showed persistent westerly winds throughout the sampling period with speeds varying between 10 and 30 mph. Wind velocity and direction exhibited little variation during the study and no diurnal patterns were apparent. Additional wind measurements at several sites along the channel revealed relatively constant westerly winds as far inland as Antioch. Pibal observations near Benicia consistently showed a distinct wind shear above the mixing layer at 1200-2500 ft above ground level (AGL) in the vicinity of the Exxon refinery (see Appendix A).

The synoptic situation over the San Franciso Bay Area was dominated by a well defined low pressure system at 500 mb during most of the field monitoring program. This low-pressure cell gave rise to cumulus development on September 20th as a high pressure system moved into the area. Overall, daytime conditions throughout the study were warm and sunny with scattered clouds appearing on most afternoons.

SITE DESCRIPTION - ANTHROPOGENIC EMISSIONS

San Francisco Bay is located along the Pacific coast in north-central California. The San Francisco Bay Area as defined by the region under the jurisdiction of the Bay Area Air Pollution Control District (BAAPCD), encompasses 6094 square miles, all but 493 of which are land area. The district includes all or parts of nine counties, as well as the urban centers of San Francisco and Oakland. In addition to nearly 5-million people who own and operate over 3-million cars, the Bay Area includes numerous industrial emission sources. The BAAPCD regulates such diverse types of industrial operations as petroleum refineries, chemical plants, power generating stations, metallurgical processors, and organic solvent users. The 1975 BAAPCD Emission Inventory Summary Report[13] lists 116 separate point sources, ranging in size from small operations like the Union Oil bulk plant at Santa Rosa (0.1 tons/day of organics), to the Standard Oil refinery at Richmond (22 tons/day organics, 20 tons/day NO_x, 12 tons/day SO_2, and 9.8 tons/day CO).

Anthropogenic sources emit substantial quantities of gaseous and particlate material into the atmosphere over the San Francisco Bay Area. Table 1 presents the BAAPCD's estimated annual average emissions from manmade sources for the entire nine county district during 1975[13].

TABLE 1. TOTAL ANTHROPOGENIC EMISSIONS-TONS/DAY

Particulates	Organics	NO_x	SO_2	CO
180	1000	660	220	3700

Table 2 further delineates Bay Area anthropogenic emissions by showing the relative contribution of major source categories.[13] From these values it is apparent that motor vehicles account for a large proportion of total man-made pollutants: 28%-particulates; 45%-organics; 57%-NO_x; 9%-SO_2; and 87%-CO. Stationary point sources are responsible for most of the additional burden.

TABLE 2. PERCENTAGE DISTRIBUTION OF BAY AREA EMISSIONS

Source	Part	ORG	NO_x	SO_2	CO
Aircraft	5	3	2	1	2
Burning of Materials	7	2	--	--	2
Chemical Industries	3	1	--	38	1
Combustion of Fuels	7	1	23	16	--
Gasoline Marketing	0	6	0	0	0
Misc. Industrial/Commercial	43	1	--	3	1
Motor Vehicles	28	45	57	9	87
Off-Highway Mobile Sources	3	4	9	12	8
Organic Compounds Evaporation	0	31	0	0	0
Petroleum Refining	4	7	7	22	--
	100%	100%	100%	100%	100%

The region northeast of San Francisco, between Richmond and Antioch, is heavily industrialized. Six petroleum refineries, five power plants, several chemical processing facilities, and various other industrial operations are located along the San Pablo Bay - Carquinez Strait - Suisun Bay corridor (see Figure 3). Forty-three separate point sources are listed in this area and it is estimated that 88.1 tons of organics and 121.2 tons of nitrogen oxides are released by these facilities daily.[13]

The Exxon petroleum refinery at Benicia was the focal point of the WSU research program. Located approximately midway between Richmond and Antioch, on the northern edge of the Carquinez Strait - Suisun Bay juncture, it is one of only two emission sources listed by the BAAPCD along the northern shore of the channel. The other is the Mare Island Naval Shipyard at Vallejo, estimated to emit 0.4 tons/day of organics and 0.8 tons/day of NO_x.[13] Because of this somewhat segregated location the Exxon plume was distinquishable for several miles downwind.

The Exxon refinery is a relatively new facility, having begun production in 1969. It has a capacity of approximately 90,000 barrels/day and produces primarily gasoline and jet fuel. Air pollution control devices in effect at the time of the study included a CO furnace on the catalytic cracking unit, a combination cyclone-electrostatic precipitator for catalyst dust recovery, a bag house on the coking unit, and floating roof storage tanks. Emissions from two sulfur recovery units, the catalytic cracking unit, the fluid coker, as well as various combustion processes were vented to the atmosphere through a 465-foot stack. Estimated annual average emissions for the Exxon refinery during 1975 were 0.8 tons/day (t/d) of particulates, 9.1 t/d of organics, 40.0 t/d of SO_2, 9.8 t/d of NO_x and 4.2 t/d of CO.[13]

Industrial emission sources to the west of Benicia, in the areas generally upwind of the Exxon refinery, emit significant quantities of air pollutants. Of particular interest in this study were the amounts of organics (hydrocarbons) and NO_x available to participate in photochemical reactions. BAAPCD figures show that point sources between Richmond and Benicia discharged 42.3 tons of organics and 35.4 tons of NO_x to the atmosphere each day.[13] This industrial contribution in combination with pollutants that might have been transported from San Francisco and Oakland formed the pollution burden of the air mass passing through the Carquinez Strait - Suisun Bay Channel. In order to estimate the relative contribution of upwind sources to oxidant formation observed to the east of Benicia, aircraft flights were performed over San Pablo Bay and the Carquinez Strait prior to sorties downwind of the Exxon plant.

Additional pollution sources are also located between Benicia and Antioch, in the region usually downwind of the Exxon refinery. These operations released an estimated 26.7 tons of organics and 76.1 tons of NO_x daily.[13] Because winds normally carried the Exxon plume along the northern edge of Suisun Bay, it remained separated for several miles from plumes originating at facilities along the southern shore.

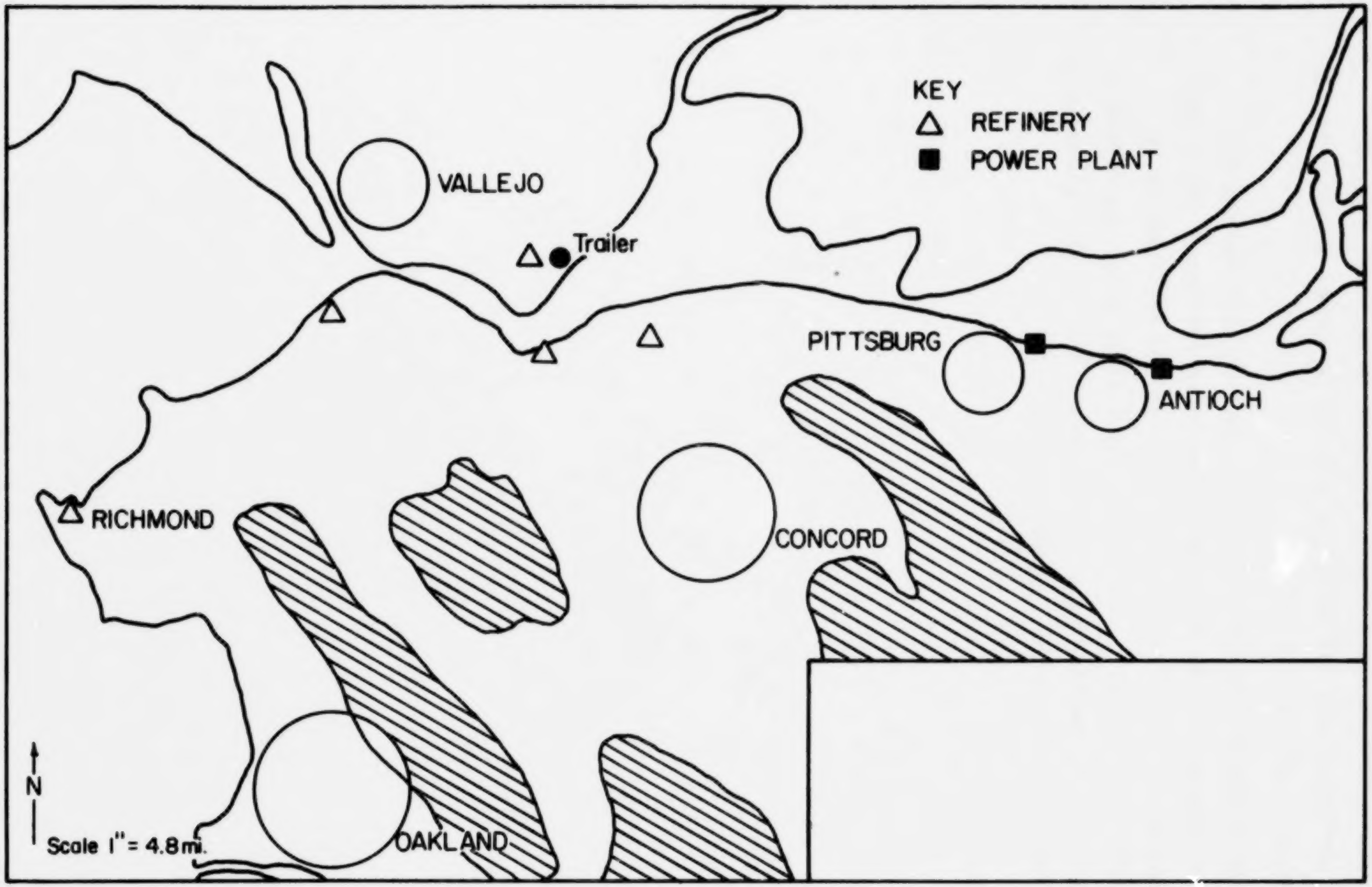
KEY
△ REFINERY
■ POWER PLANT
VALLEJO
Trailer
PITTSBURG
ANTIOCH
RICHMOND
CONCORD
OAKLAND
N
Scale 1" = 4.8 mi.

Figure 3. Map showing important industrial emission sources between Richmond and Antioch.

SECTION 2

CONCLUSIONS

Elevated condensation nuclei (CN) levels associated with refinery emissions were used to define plume boundaries at distances up to eight miles from the Exxon plant. Atmospheric dispersion processes and/or interferences from other anthropogenic emission sources prevented tracking of the Exxon plume for further distances downwind. Increased concentrations of total hydrocarbon (THC), non-methane total hydrocarbons (NMTHC), carbon monoxide (CO) and nitrogen oxides (NO_x), as well as decreased ozone (O_3) levels were observed within the Exxon effluent at distances less than five miles from the refinery complex. Elevated in-plume concentrations of CN and NMTHC persisted out to eight miles, while NO_x, O_3, and CO levels did not differ significantly from ambient background concentrations at distances greater than 5 miles downwind. Most of the hydrocarbons observed in the refinery plume were paraffinic compounds with ethane, propane, i-butane, n-butane, i-pentane and n-pentane the dominant species.

Natural sunlight bag irradiation experiments performed during the field monitoring program indicated that Exxon emissions had definite photochemical ozone forming potential. Although ambient background samples taken out of the plume showed little or no photochemical activity, in-plume samples exhibited ozone production in every instance, with maximum ozone produced varying from 15 to 80 ppb. Maximum ozone formation was observed to vary with NMTHC/NO_x ratios and to a lesser extent the absolute NMTHC concentration. Peak ozone formation was measured at NMTHC/NO_x ratios of approximately 15.

Aircraft flights designed to monitor photochemical oxidant formation within the Exxon plume did not document any instance of in-plume ozone levels in excess of ambient background concentrations. Ozone concentrations to the west (upwind) over San Pablo Bay typically varied between 35 - 45 ppb.

Aircraft measurements to the east of Benicia consistently showed a gradual ozone buildup as the plane moved inland. Ozone concentrations in the delta region commonly exceeded 80 ppb, with values above 100 ppb recorded on at least one occasion. All available evidence suggests that the observed ozone buildup in the river delta region to the east of Antioch results primarily from precursor emissions upwind along the heavily industrialized channel between Richmond and Antioch.

SECTION 3

EXPERIMENTAL

The ambient air monitoring program near the Exxon refinery at Benicia involved both ground-level and aircraft sampling systems. The monitoring network was designed specifically to measure light hydrocarbons near the refinery complex and provide information on changes in plume chemistry during transport downwind. Ground operations centered around an instrumented trailer located approximately 1.5 miles east of the plant. A specially equipped Cessna 336 Skymaster was used to conduct airborne sampling throughout the region. All measurements were accomplished during September 8-22, 1975.

GROUND MEASUREMENTS

A 23-foot instrumented trailer served as a field laboratory for this project. The trailer contains approximately 52 ft of bench and work space, which provides adequate room for monitoring instruments, meteorological sensors, and a data aquisition system. Constant temperature within the field laboratory is maintained by two large air conditioners mounted on the roof. Outside air enters the trailer through a 4-inch diameter stainless steel line with the top of the inlet stack 20 feet above ground level. This sample line runs the full interior length of the trailer and serves as a manifold for supplying outside air to the continuously monitoring instruments. A squirrel cage fan at the exhaust end maintains an air flow rate of approximately 100 cfm through the system. Those instruments monitoring the most reactive gases, ozone and nitric oxide, are closest to the inlet of the manifold.

Instruments within the field laboratory provided for continuous measurement of O_3, NO, NO_2, NO_x, CO, CH_4, total hydrocarbons (THC), selected halocarbons, and important meteorological variables. In addition, hydrocarbon samples collected at remote sites or onboard the aircraft were returned to the trailer for detailed gas chromatographic analysis (see Table 3). The output from the TECO, Meloy, Climet and Beckman instruments was recorded on magnetic tape for later computer reduction. The output from the two Perkin Elmer gas chromatographs was channeled directly into the Hewlett Packard 3352 data system.

TABLE 3. GROUND MEASUREMENTS DURING BENICIA REFINERY STUDY

Parameter-instrument

oxides of nitrogen - TECO 14D

temperature discontinuities aloft - Aerovironment Acoustical Sounder

ozone - Meloy OA 350

carbon monoxide
methane - Beckman 6800 AQGC
total hydrocarbon

winds aloft - Warren Knight Model 14 Double Center Theodolite

individual hydrocarbons - 2 Perkin Elmer 900 GC's
(C_2-C_5 and C_6-C_{10})

halocarbons - Hewlett Packard 5700A GC

wind speed
wind direction
dew point - Climet CI-60
temperature
solar radiation

The following is a brief description of the instruments used to make the measurements listed in Table 3.

Ozone Measurement - Meloy Model OA350 Ozone Analyzer. Operation of this instrument is based on the gas-phase chemiluminescent reaction between ozone and ethylene. It provided dependable, trouble-free operation throughout the study period.

NO, NO_2 and NO_x Measurements - TECO Model 14D. This instrument employs the chemiluminescent reaction between nitric oxide and ozone as the detection technique.

Methane, Carbon Monoxide and Total Hydrocarbon Measurements - Beckman Model 6800 Air Quality Gas Chromatograph. This automated gas chromatograph employs a flame ionization detector for hydrocarbon analysis. Carbon monoxide is reduced to methane prior to entering the detector.

Halocarbon Measurements - Hewlett Packard Model 5700A Gas Chromatograph. This instrument was equipped with a constant-current ^{63}Ni electron capture detector. Separation of fluorocarbon-11, chloroform, carbon tetrachloride and 1,1,1-trichloroethane was achieved on a 10-ft x 1/8 in. stainless steel column containing 10% SF-96 Chromosorb W. The column was maintained at 55°C. With a carrier gas (95% argon-5% methane) flow of 20 ml/min., four analyses could be run each hour. This instrument was automated by attaching a 1-ml sample loop, a Carle microvalve (#5518), a Carle valve actuator (#4201) and a Carle valve minder (#4101). A manual injection technique was used for aircraft-collected samples.

Individual Hydrocarbon Measurements - Two Perkin Elmer Model 900 Gas Chromatographs. These standard dual-flame instruments were used with the addition of a sub-ambient accessory. The normal carrier gas flow system was modified to include a freeze-out trap for concentrating the organics in ambient air. The column used to separate light hydrocarbons (C_2-C_5) was a packed capillary (20'x 1/16") containing Durapak n-octane/Porasil C. A 200-ft OV-101 SCOT column was used on selected samples to separate C_6-C_{10} hydrocarbons. Samples for hydrocarbon analysis were taken from the trailer manifold, plastic bags or stainless steel canisters. The latter two collection devices allowed samples to be taken at remote sites or on board the aircraft for subsequent GC analysis at the field laboratory.

Climet CI-60 Data System - This instrument package contains sensors for measuring wind speed, wind direction, dew point, temperature and solar radiation. Turbulence was also determined from wind speed and wind direction perturbations. Output from the various sensors is channeled into a translator which conditions the signals and provides an output voltage compatible with a multi-pen recorder or other data-logging device.

Aerovironment Model 300 Monostatic Radar - This acoustic sounder measures the turbulent fluctuation of atmospheric temperature on electrosensitive chart paper. A continuous record of the intensity of echo return as a function of height and time is obtained. The instrument has a maximum vertical range of 1000 meters.

Warren Knight Model 84 Double Center Theodolite - Pilot balloons were used in conjunction with this theodolite for monitoring upper-level wind speed and direction. The balloons were of the 30g type and the standard rise rate table was used for computations.

Natural sunlight bag irradiation experiments were also carried out at the trailer site to examine the photochemical potential of refinery emissions. Air samples collected in 400 liter Teflon or Tedlar bags were irradiated with natural sunlight for six hours with changes in NO_x, O_3 and hydrocarbon (HC) concentrations monitored at periodic intervals. Additional amounts of NO_x were added to some plume samples in order to investigate the effect of changes in HC/NO_x ratio on ozone production.

AIRCRAFT MEASUREMENTS

A center line thrust, twin engine Cessna 336 Skymaster was employed to conduct airborne sampling operations. This airplane is capable of carrying the pilot, instrument operator, about 400 lbs. of instrumentation and enough fuel for four hours of survey work. Air for the sampling instruments is brought in through a 4-in. diameter air scoop extending out approximately 10-in. from the fuselage. The air scoop and connecting 3-in. Plexiglas pipe inside the airplane cabin were designed to bring a large flow of sample air into the plane.

The plane was equipped with two 60-amp alternators. A Topaz solid-state inverter was used to convert the 28-VDC alternator output to 120-VAC for operating the air pollutant analyzers. This inverter provided about 1500 watts of usable power, which was more than sufficient for operation of the various instruments.

Instrumentation on board the aircraft allowed for continuous measurement of O_3, NO, NO_2, NO_x, visual range, condensation nuclei, as well as various meteorological and navigation parameters (see Table 4). The output from these instruments was sequentially recorded each 0.4 second (equivalent to 55 feet in level flight at 90 MPH) on a Metrodata System four-track magnetic tape cartridge. Hydrocarbon grab samples were obtained by using a Metal Bellows pump to fill Teflon bags and/or stainless steel cans.

TABLE 4. AIRCRAFT MEASUREMENTS DURING THE BENICIA REFINERY STUDY

Parameter-instrument
oxides of nitrogen - Monitor Labs 8440
ozone - Bendix 8002
visual range - MRI integrating nephelometer
condensation nuclei - Environment One Rich 100
temperature, relative humidity, dew point and navigational parameters - Metrodata M8

The following is a brief description of the instruments listed in Table 4.

NO, NO_2 and NO_x Measurements - Monitor Lab 8440 instrument was used to measure oxides of nitrogen. This instrument employs the chemiluminescent reaction between nitric oxide and ozone as the detection technique. The 8440 has dual chambers, one for NO and and another for NO_x, and is capable of selective detection of NO, NO_2, and NO_x. It has a lower sensitivity limit of approximately 5 ppb for each of these compounds.

Ozone Measurements - A Bendix Model 8002 chemiluminescent analyzer was used to monitor ozone levels aloft. The response time (<10 sec) of this instrument is sufficiently rapid for meaningful aircraft measurements. The only problem encountered with this analyzer was zero shifts accompanying cabin temperature changes. This problem could be alleviated somewhat by keeping the instrument running while the aircraft was on the ground; however, on very warm days it was necessary to include a spiral climb immediately after take-off to cool the interior of the aircraft.

Condensation Nuclei - An Environment One Rich 100 analyzer was used to measure very small particulate material in the atmosphere.

Visual Range - A MRI Integrating Nephelometer modified to increase its sensitivity was used to monitor light scattering and visual range. Air was not dried before entering the analyzer tube so changes in atmospheric humidity must be taken into account when examining these data.

Temperature, Relative Humidity and Navigational Parameters - A Metro-odata M8 Airborne Meteorological and Navigational System was used to measure temperature, humidity, airspeed, altitude, bearings from two points (VOR) and distance from one point (DME). The temperature and humidity data are derived from sensors mounted under the aircraft wing. The airspeed and altitude systems use potentiometric transducers which are connected to the aircraft pitot-static system. VOR/DME data are acquired from navigational receivers installed in the aircraft. Mapping of flight paths was accomplished through the use of continuously collected VOR and DME signals plus a visual record kept by the pilot and instrument operator aboard the aircraft.

Bag/Can Samples for Hydrocarbon and Halocarbon Analysis - A manifold was constructed in the rear portion of the aircraft cabin that permitted rapid collection of bag samples for subsequent analysis in the ground laboratory. Five-liter bags could be filled in about 15 sec by ram air from the sample line, while bags of 30-liter capacity took about one minute to fill. Stainless steel canisters were filled using a Metal Bellows pump.

CALIBRATION PROCEDURES

A comprehensive data quality control program is an essential part of all field studies. Instrument calibration and zero checks must be documented so that any questions concerning data quality can be resolved. We kept daily records of these events and have used this information in arriving at the numbers provided in this report. Any data that appeared questionable was not included. A summary of precautions taken to insure data integrity for the various measurements is provided below.

Ozone - The ground based and airborne analyzers were calibrated at least once a week using a McMillan Model 1000 ozone generator. This ozone source was specially designed to provide outputs in the 20 to 200 ppb range. Absolute calibration of the McMillan generator was based on the standard KI method plus spectral measurements using a Dasibi Model 1003-AH ultraviolet ozone photometer.

A zero check was made once a day on the ground ozone instrument, while in the aircraft numerous checks were made during each flight. The airborne ozone data has been adjusted for zero drift whenever necessary. Ozone analyzers of the type used in this study respond to changes in atmospheric pressure. Ground level pressure changes are minor and need not be of concern; however, when an instrument is carried aloft by aircraft, pressure factors must be considered. All of our aircraft collected ozone data have been corrected for altitude using equations developed from pressure chamber studies.

Oxides of Nitrogen - Our calibration source for the TECO and Monitor Labs instruments was a tank containing 5.8 ppm NO. Linearity checks were made by diluting the 5.8 ppm standard in Teflon bags. A calibration check was performed once a week and zero checks daily.

Total Hydrocarbon, Methane and Carbon Monoxide - The Beckman 6800 AQGC was calibrated using a tank containing 7.9 ppmC (THC), 2.19 ppm methane and 3.00 ppm carbon monoxide. Calibration checks were made about every other day. Toward the end of the study we received a standard from EPA-RTP that was reported to contain 0.44 ppm CO. We ran this standard and determined a concentration of 0.47 ppm, which is certainly in good agreement.

Fluorocarbon-11 and Carbon Tetrachloride - The electron capture gas chromatograph was calibrated by making up standards in ambient air. At the present time we feel this is the best method since the moisture and oxygen content of the standard will be nearly the same as in samples collected during routine analysis periods. The calibration was based on a Freon-11 standard that had been certified by mass spectrometry. At the beginning of the field study, measured volumes of the 11 ppm standard were added to a 45-liter carboy filled with ambient air. From this a peak height versus concentration curve was obtained for the concentration region of interest (100-400 ppt). During this initial calibration period a stainless steel canister was filled with ambient air and the fluorocarbon-11 concentration was determined based on the calibration described above. Samples from this canister were run daily throughout the study period in order to monitor stability of the electron capture detector. Carbon tetrachloride calibration was carried out in a similar manner.

Individual Hydrocarbons - Identification of the hydrocarbons was based on retention time comparisons. Resolution of light hydrocarbons on Durapak n-Octane/Porasil C column was excellent and retention times were extremely reproducible. Thus, little difficulty existed in making unambiguous peak identifications. Calibration of the Perkin Elmer gas chromatographs was achieved by measuring instrument response of known concentrations of hexane in air. Three different hexane sources were used to prepare standards in the ppb range. In the field, an internal standard (neo-Hexane, .209 ppm) was included in each air analysis in order to insure calibration reliability.

Meteorological Parameters - Calibration curves supplied by the manufacturer were used to convert the Climet CI-60 sensor output signals to the appropriate temperature, wind speed, etc. readings. While in the field, sensor signals were checked routinely to insure correct operation.

Particulate Measurements - The condensation nuclei counter and nephelometer were calibrated in the home laboratory prior to going into the field. No calibration checks were made in the field since their primary function was not to provide absolute numbers but rather to determine gross horizontal and vertical CN and/or light scattering inhomogenities within an air mass.

SECTION 4

RESULTS AND DISCUSSION

PLUME DIMENSIONS

Locating and defining plume boundaries are basic to any attempt at studying petroleum refinery emissions. Aircraft traverses perpendicular to the prevailing wind direction were flown downwind of the Exxon plant in order to establish plume boundaries. Responses from various onboard instruments such as changes in CN, NO_x and O_3 levels were used to track the refinery effluent and determine its dimensions. Hydrocarbon grab samples in the plume were returned to the field laboratory for analysis and provided additional verification that the aircraft was definitely sampling emissions from the Exxon refinery.

The plume was most easily distinquished from background ambient air through increased CN counts. As the aircraft entered the plume there was a dramatic increase in CN followed by an abrupt return to ambient levels as it exited. Elevated CN levels were used to track the Exxon plume at distances up to eight miles from the refinery. The persistently high CN levels observed in the plume and the quick response of the Environment One instrument combined to make condensation nuclei levels the single best indication of plume boundaries throughout the field program.

When sampling near the Exxon plant (0-3 miles) ozone and oxides of nitrogen levels could also be used to distinquish the plume from background air. Increased concentrations of NO_x and decreased concentrations of ozone were routinely measured in the refinery plume at distances less than three miles downwind. The inverse relationship between NO_x and O_3 commonly observed in the Exxon plume undoubtedly results from the well established scavenging of ozone by nitric oxide. At distances greater than five miles, little or no difference was noted between in-plume and ambient background levels of both NO_x and O_3.

Results from an aircraft traverse of the Exxon plume three miles downwind of the plant at 650 feet AGL are summarized in Figure 4. These data are typical of cross-plume passes at distances less than five miles from the refinery. In-plume NO_x levels are approximately 80 ppb above background concentrations, while maximum ozone depletion is on the order of 20 ppb. Based on increased CN values the plume is approximately one mile wide at this point.

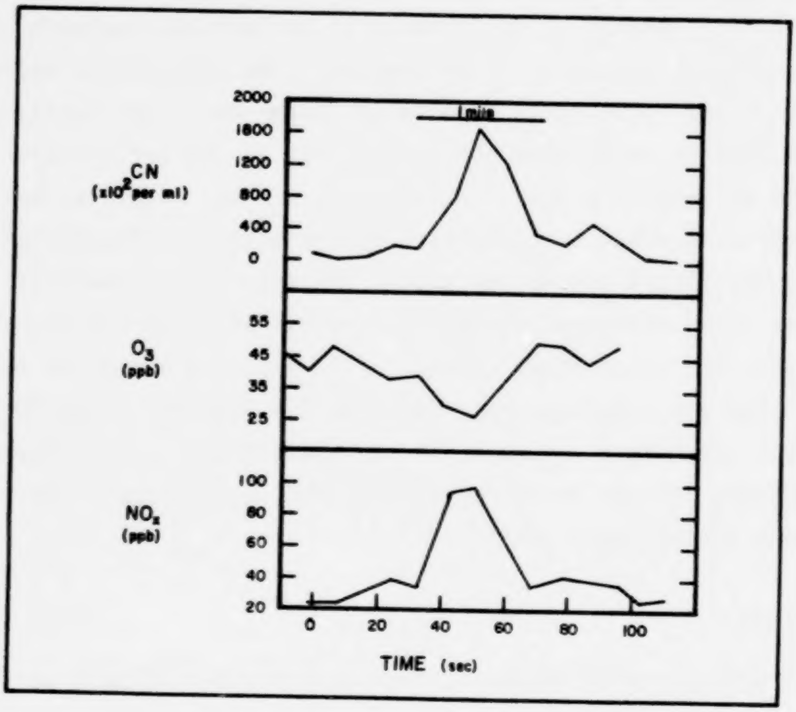

Figure 4. Aircraft traverse of the Exxon plume three miles downwind of the plant at 650 ft. AGL.

Plume dimensions were normally established on the basis of elevated CN levels with the points where CN values returned to background concentrations approximating plume boundaries. Data from all cross-plume passes indicate plume dimensions usually expanded rapidly between one to three miles from the plant and then remained relatively constant out to eight miles. At its widest the Exxon plume was typically 1 to 2.5 miles across and in no instance exceeded 3 miles in width. Plume traverses for each flight are contained in Appendix B.

As mentioned earlier, the Exxon refinery is the only major industrial emission source along the north shore of the San Pablo Bay - Carquinez Strait - Suisun Bay channel. However, from Richmond to Antioch the southern shore is dotted with one industrial plant after another. The atmospheric emissions from these operations resulted in a pollutant plume which was easily distinquishable from ambient background air as far east as the delta region of the San Joaquin and Sacramento Rivers. Elevated CN and NO_x levels as well as increased hydrocarbon concentrations were observed in this "southern" plume on virtually every flight during the study. Because of the somewhat isolated position of the Exxon refinery and the fanning out of winds exiting the Carquinez Strait, the Exxon plume was typically observed along the northern edge of Suisun Bay and remained separated from the southern plume for several miles. Figure 5 presents a schematic of the approximate plume centerlines most often recorded for the Exxon refinery as well as the Shell and Phillips refineries along the southern shore.

PLUME COMPOSITION

Information on gross plume composition was obtained through aircraft measurements downwind of the refinery and ground-level samples collected near the Exxon fenceline. Monitoring efforts focused on characterizing gaseous constituents of the plume with particular emphasis on non-methane total hydrocarbon (NMTHC), NO_x and O_3 concentrations. Aircraft grab samples and integrated samples collected at the surface were returned to the WSU trailer for detailed hydrocarbon analysis. In most instances, samples were also taken just outside plume boundaries and/or above the mixing layer in order to provide a basis for comparison.

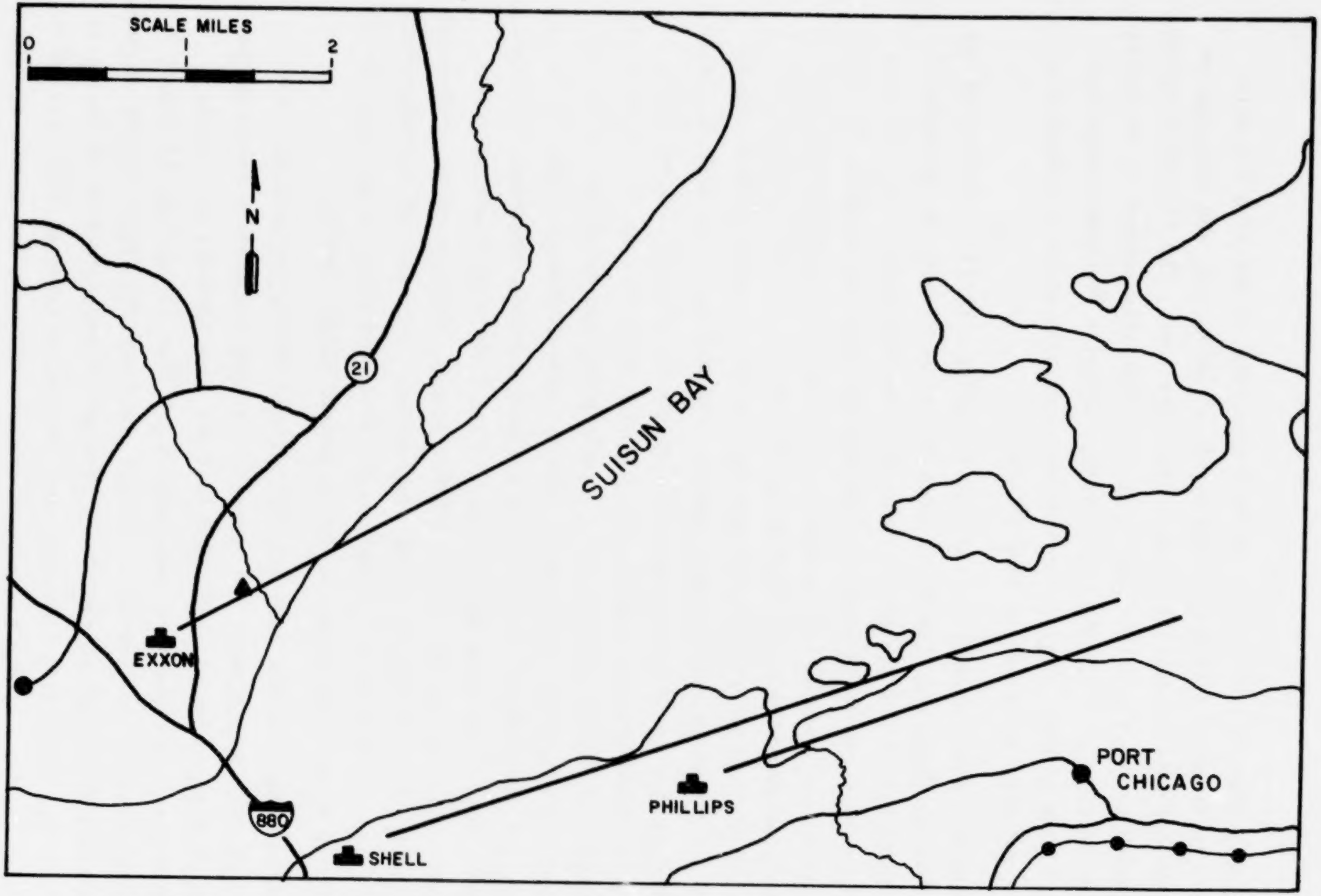
SCALE MILES
0
1
2
N
21
SUISUN BAY
EXXON
880
SHELL
PHILLIPS
PORT CHICAGO

Figure 5. Schematic of the approximate plume centerlines most often observed for the Exxon, Shell and Phillips refineries.

Results from aircraft passes through the plume in the area 0-5 miles downwind consistently showed elevated levels of NMTHC, NO_x and condensation nuclei (CN) as well as depressed ozone concentrations. The inverse relationship between nitric oxide (NO) and ozone was especially evident at distances less than three miles from the Exxon plant. Slightly elevated carbon monoxide (CO) and methane (CH_4) concentrations were also noted in conjunction with the refinery emissions on some flights.

Figures 6 and 7 present data collected during aircraft traverses of the Exxon plume at three and five miles downwind, respectively, on September 9, 1975. These values are typical of concentrations measured in the refinery plume throughout the field study and reflect the observed in-plume stratification of NO_x, O_3 and CN. While highest NMTHC and CN concentrations were invariably measured below 500 feet above mean sea level (MSL), highest NO_x levels and maximum ozone depletion were most often recorded between 600-900 feet MSL. This situation probably results from the fact that most NO_x emissions are emitted to the atmosphere through the 465-foot stack, while the majority of hydrocarbon discharges are fugitive emissions due to evaporative-type losses at or near ground level. In-plume NO_x concentrations of 80-150 parts per billion (ppb), compared to typical ambient concentrations of 30 ppb or less, and ozone depletions of 20-25 ppb were commonly observed at distances less than three miles from the refinery. Past five miles downwind plume associated ozone values approached ambient levels, although slightly elevated NO_x concentrations persisted out to eight miles. Increased CN readings within the Exxon effluent were recorded in all instances where it was possible to distinquish between the plume and background pollutant levels.

Information obtained from aircraft spirals during the morning flight (0955-1200 PDT) on September 9th revealed a strong temperature inversion extending from approximately 1200-2800 feet MSL (See Appendix B). Ozone concentrations increased from less than 35 ppb near the surface to almost 70 ppb at the base of the inversion. Within the inversion, ozone levels decreased slightly and then remained relatively constant at approximately 70 ppb up to 6000 feet MSL. This data indicates that the sample taken at 1100 feet MSL is just below the base of the temperature discontinuity and the sample at 1600 feet MSL (Figure 6) is above the mixing layer, but still within the inversion.

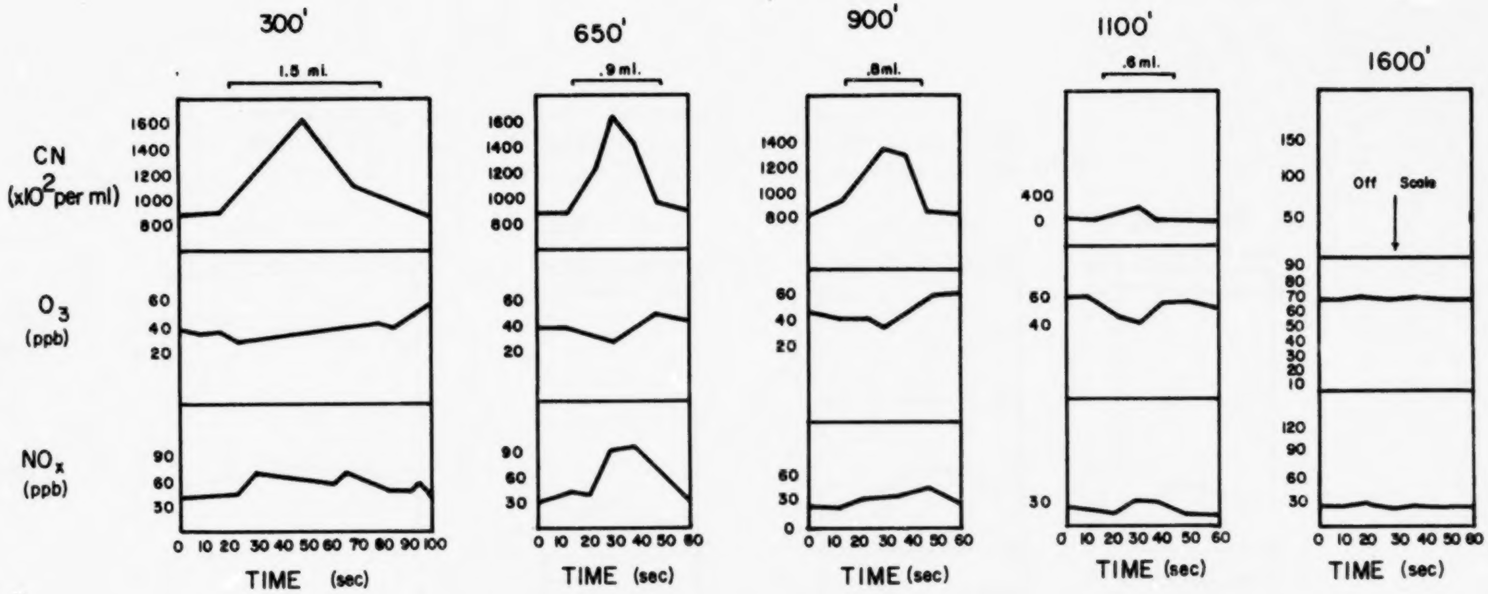

Figure 6. Plot of variations in CN, O_3 and NO_x concentrations measured during aircraft traverses of the Exxon plume three miles downwind of the plant on September 9. 1975.

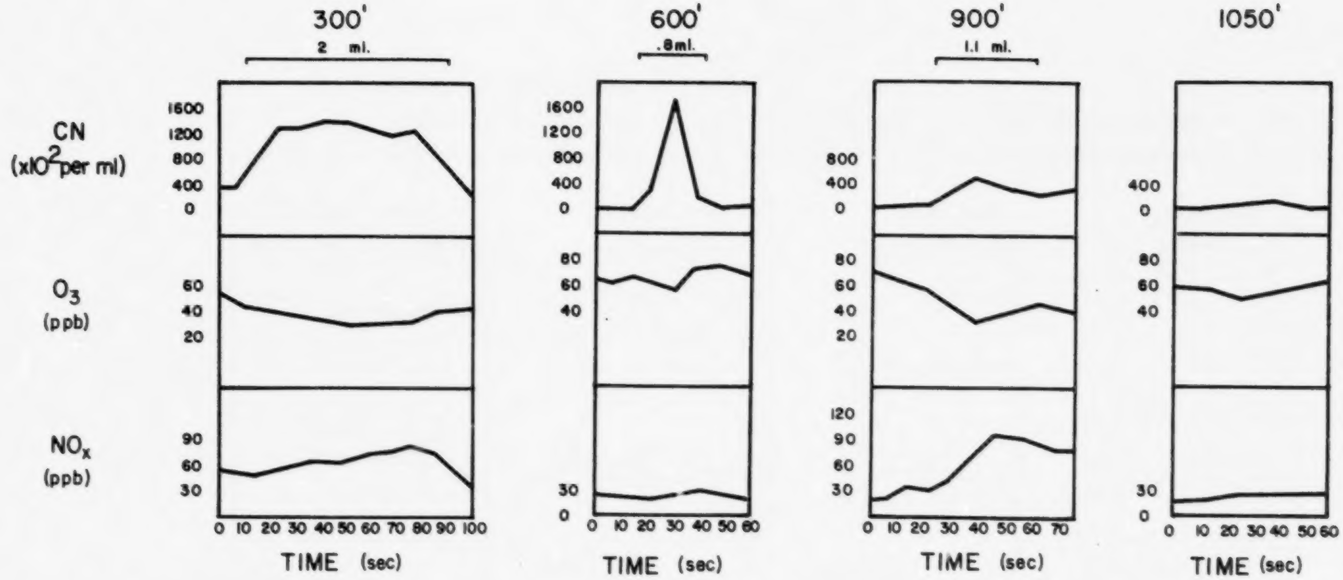

Figure 7. Plot of variations in CN, O_3 and NO_x concentrations measured during aircraft traverses of the Exxon plume five miles downwind of the plant on September 9, 1975.

Hydrocarbons are an important component of refinery emissions and special emphasis was placed on characterizing the types and amounts of individual compounds within the plume. Gas chromatographic analysis was used to provide detailed identification of hydrocarbon species in the C_2-C_6 weight range. Selected samples were also tested for heavier hydrocarbons in the C_7-C_{10} range.

Results from analyses of the aircraft collected hydrocarbon samples show that there was typically a 2 to 10-fold increase in NMTHC levels within the definable portion of the plume. Highest values were normally recorded between 300-500 feet MSL with concentrations decreasing up to the base of the temperature inversion. As would be expected, absolute hydrocarbon levels were highest near the refinery and decreased gradually out to eight miles. At distances less than three miles downwind of the plant, C_2-C_6 hydrocarbon levels in the plume often exceeded 120 $\mu g/m^3$ at 300 feet MSL. Hydrocarbon concentrations were still elevated within the refinery effluent at eight miles, but levels rarely exceeded 90 $\mu g/m^3$. Saturated hydrocarbons were always the dominant compounds in the plume, especially ethane, propane, i-butane, n-butane, i-pentane and n-pentane. The most frequently observed heavier hydrocarbons included 3-methylpentane, hexane, 2,3-dimethylpentane, 3-methylheptane and toluene. Unsaturated hydrocarbon species normally accounted for less than eight percent of the total, with acetylene levels typically less than 3 $\mu g/m^3$.

Table 5 summarizes light hydrocarbon data collected by the aircraft on the morning of September 9th approximately three miles downwind of the refinery. All of the in-plume samples were taken at approximately the same time, altitude and distance downwind as the plume traverses listed previously in Figure 6. The values presented are similar to other samples collected at comparable altitudes and distances during the course of the monitoring program. The data clearly indicate that the highest C_2-C_6 hydrocarbon concentration was measured at 300 feet MSL, with values decreasing up to the top of the mixing layer. The sample at 1600 feet MSL is above the Exxon plume yet still within the deep temperature inversion. The 6000 foot sample is well above the temperature discontinuity and represents a situation relatively

TABLE 5. SUMMARY OF LIGHT HYDROCARBON DATA 3 MILES DOWNWIND OF THE REFINERY ON SEPTEMBER 9, 1975

	Concentration ($\mu g/m^3$)					
	6000'	1600'	1100'	900'	650'	300'
ethane	4.0	4.5	5.0	19.0	26.5	41.5
ethylene	*	1.0	1.5	3.0	3.0	5.5
acetylene	*	*	1.5	2.0	1.5	2.0
propane	3.0	2.0	2.5	12.0	21.0	32.0
propene	*	*	*	1.0	1.5	1.5
i-butane	*	1.0	1.5	5.5	8.5	11.0
n-butane	*	1.5	2.5	8.5	13.0	17.0
1-butene	*	*	*	*	*	*
i-butene	*	1.0	0.5	1.0	0.5	1.0
t-2-butene	*	*	*	*	*	*
propyne	*	*	*	*	*	*
c-2-butene	*	*	*	*	*	*
i-pentane	*	2.0	3.5	9.0	13.5	20.0
n-pentane	*	1.0	1.5	3.5	5.5	7.5
cyclopentane	*	*	*	*	*	*
1-pentene	*	*	*	*	*	*
i-hexane	-	-	-	-	-	-
3-m-pentane	-	-	-	-	-	-
n-hexane	-	-	-	-	-	-
Σolefins	0	2.0	2.0	5.0	4.0	6.5
Σparaffins	7.0	12.0	17.5	57.5	89.0	130.5
Total $\mu g/m^3$	7.0	14.0	21.0	64.5	94.5	139.0
Total ppmC	0.01	0.02	0.03	0.10	0.15	0.22
CH_4 (ppm)	-	1.7	1.6	1.7	1.9	2.0
CO (ppm)	-	0.4	0.5	0.6	0.6	0.7
$CFCl_3$ (ppt)	-	-	-	-	-	-
CCl_4 (ppt)	-	-	-	-	-	-

* < 0.5 $\mu g/m^3$ - missing data

free from boundary layer effects. From the information presented it is apparent that in-plume samples exhibit substantially higher light hydrocarbon levels than those collected above the base of the temperature inversion. The 140 $\mu g/m^3$ measured at 300 feet MSL is a 10-fold increase over the 1600 foot sample and a 20-fold increase over the sample at 6000 feet. Saturated hydrocarbons are definitely the dominant compounds with olefinic species accounting for less than six percent of the total in each case.

Ground-level hydrocarbon measurements also showed marked differences between in-plume and out-of-plume samples. Light hydrocarbon (C_2-C_6) levels within Exxon plume boundaries at 0.5 miles downwind typically showed a 5 to 15-fold increase over ambient background concentrations. At distances less than a mile from the refinery C_2-C_6 hydrocarbon values in the plume ranged from 102 to 446 $\mu g/m^3$ (avg. 225), while samples collected out of the plume near the WSU trailer ranged between 10 and 69 $\mu g/m^3$ (avg. 39). As with aircraft collected samples, the bulk of ground-level hydrocarbon emissions from the Exxon plant were composed of saturated compounds (ethane, propane, i-butane, n-butane, i-pentane and n-pentane). Often times n-butane and i-pentane alone accounted for over fifty percent of the total light hydrocarbon burden in samples near the refinery at ground level. Samples representative of background ambient air in this same vicinity, although containing much lower hydrocarbon concentrations were also comprised primarily of these same saturated species.

Table 6 presents the results of ground-level hydrocarbon measurements on September 19, 1975. In addition to the usual in-plume and ambient air samples normally collected, three samples were taken near the refinery fenceline and two samples were obtained from a parking lot and a garage in downtown Benicia. These latter two samples were collected in areas where auto exhaust was the primary source of hydrocarbon emissions. The data clearly show elevated light hydrocarbon levels associated with emissions from the Exxon refinery. Highest concentrations were measured at the west and east end of the refinery complex, while the sample taken approximately 0.5 miles downwind compares closely to that taken on the south edge of the the plant. Analyses of the auto exhaust samples show substantially higher levels of

TABLE 6. SUMMARY OF GROUND-LEVEL LIGHT HYDROCARBON MEASUREMENTS ON SEPTEMBER 19, 1975

	Concentration ($\mu g/m^3$)						
	G-1	G-2	G-3	G-4	G-5	G-6	G-7
ethane	4.0	3.5	6.0	8.5	3.0	10.0	10.5
ethylene	1.0	1.0	1.0	1.5	*	25.0	25.5
acetylene	*	*	*	1.0	*	28.5	16.5
propane	1.0	3.5	36.0	12.5	6.0	7.0	5.0
propene	*	*	0.5	1.0	*	13.0	9.0
i-butane	0.5	8.0	31.0	9.0	16.5	18.0	22.0
n-butane	1.5	36.0	44.0	12.5	105.0	49.5	50.0
1-butene	*	*	1.0	1.0	*	3.5	2.5
i-butene	0.5	1.5	2.0	1.0	1.0	6.0	7.0
t-2-butene	*	*	2.5	2.0	1.0	8.5	8.5
propyne	*	*	*	*	*	*	*
c-2-butene	*	*	*	*	*	*	*
i-pentane	1.5	43.5	67.5	45.0	115.5	117.0	129.5
n-pentane	*	12.5	18.5	9.0	32.0	36.5	43.0
cyclopentane	*	1.5	2.5	1.5	4.0	3.5	18.0
1-pentene	*	*	*	*	*	*	*
i-hexane	*	8.0	18.5	10.0	21.0	40.5	48.0
3-m-pentane	*	4.5	11.5	6.0	12.5	24.5	29.5
n-hexane	*	5.0	10.0	3.0	12.0	29.0	3.0
Σolefins	1.5	2.5	7.0	6.5	2.0	56.0	52.5
Σparaffins	8.5	126.0	245.5	117.0	327.5	335.5	358.5
Total $\mu g/m^3$	10.0	128.5	252.5	124.5	329.5	420.0	427.5
Total ppmC	0.02	0.20	0.39	0.19	0.50	0.64	0.65

SAMPLE LOCATION

G-1	WSU trailer site at 1000 PDT
G-2	0.5 mile downwind of Exxon at 0930 PDT
G-3	West end of Exxon Refinery
G-4	South edge of Exxon Refinery
G-5	East end of Exxon Refinery
G-6	Parking Garage
G-7	Parking Lot

* < 0.5 $\mu g/m^3$ - missing data

olefins and acetylene than were observed in either the background or refinery plume samples.

PLUME CHEMISTRY

Because petroleum refineries emit significant quantities of non-methane hydrocarbons (NMTHC) and lesser amounts of NO_x, it has been suggested that under certain conditions refinery emissions might generate photochemical ozone in excess of ambient background levels. Little research has been done on this possibility and a major portion of the WSU monitoring program was directed towards studying plume chemistry. Natural sunlight bag irradiation experiments were used to examine the potential of refinery emissions to participate in photochemical reactions resulting in net ozone production. In addition, specially designed flight paths were flown periodically in order to investigate in-plume ozone concentrations and compare these values with ambient background levels in the vicinity of the refinery. During the 8-22 September sampling period, captive air irradiations were performed on eight days and a total of eight flights aimed specifically at monitoring plume related ozone were flown on six separate days.

Bag irradiation studies were used to assess the potential of Exxon refinery emissions to produce photochemical ozone. This technique has been employed previously to determine the photochemical potential for various types of air masses.[14,15] The procedure employed during the WSU field study involved collecting three separate samples in 400-liter Teflon or Tedlar bags. Normally, two samples were collected in the Exxon plume approximately 0.5 miles downwind and a third, out of the plume, was taken near the WSU field laboratory. One of the in-plume samples was usually "spiked" with additional NO in order to investigate the effect on ozone formation of varying $NMTHC/NO_x$ ratios. The bags were irradiated with natural sunlight for six to eight hours with changes in NO_x, O_3 and NMTHC levels monitored periodically.

All irradiation experiments were conducted between September 14-21 and the results are summarized in Table 7. Results from these studies suggest that little ozone forming potential existed in ambient background air. With

TABLE 7. SUMMARY OF ALL NATURAL SUNLIGHT BAG IRRADIATION EXPERIMENTS PERFORMED DURING THE SEPTEMBER 8-22, 1975 SAMPLING PERIOD

Date	Type of sample	NO_x[a] (ppb)	NMHC[b] (ppbC)	$O_{3_i} \rightarrow O_{3_{max}}$[c] (ppb)	$NMTHC/NO_x$
9/14/75	Plume	22		4 - 48	
	Non-plume	7		17 - 21	
	Non-plume	11		16 - 17	
9/15/75	Plume	7	320	19 - 33	46
	Plume	12	320	12 - 30	27
	Non-plume	13		13 - 33	
9/16/75	Plume	23	480	0 - 30	21
	Plume[d]	126	480	2 - 27	4
	Non-plume	21		3 - 39	
9/17/75	Plume	35	740	0 - 38	21
	Plume	39	740	1 - 48	19
	Non-plume	31	220	1 - 23	7
9/18/75	Plume	32	900	4 - 42	28
	Plume[d]	46	900	2 - 63	19
	Non-plume	12	60	12 - 28	5
9/19/75	Plume	14	315	10 - 23	22
	Plume[d]	40	315	3 - 45	8
	Non-plume[d]	13		18 - 26	
9/20/75	Plume	50	720	2 - 81	14
	Non-plume	42		1 - 48	
	Non-plume[d]	69		0 - 53	
9/21/75	Plume[d]	24		4 - 84	
	Non-plume	18		9 - 33	
	Non-plume[d]	45		4 - 35	

[a] Initial NO_x concentration.
[b] Initial HC concentration.
[c] Range between initial and maximum O_3 concentration.
[d] Additional NO added.

the exception of the non-plume samples on September 20, maximum ozone formation outside the plume ranged between 1-33 ppb. Samples collected in the Exxon plume, however, consistently exhibited substantial photochemical ozone production with maximum ozone increases varying between 15 and 80 ppb.

Figure 8 portrays the data obtained from captive air irradiations on September 18, 1975. The in-plume samples definitely generated ozone levels in excess of the approximately 15 ppb increase observed in the background sample. In this case, the unaltered refinery emissions generated a maximum of approximately 40 ppb ozone while the plume sample spiked with additional NO resulted in a maximum of approximately 60 ppb. On two occasions irradiation of in-plume samples generated peak ozone levels in excess of 80 ppb, one on September 20 in a sample spiked with NO and again on the 21st in an unaltered plume sample.

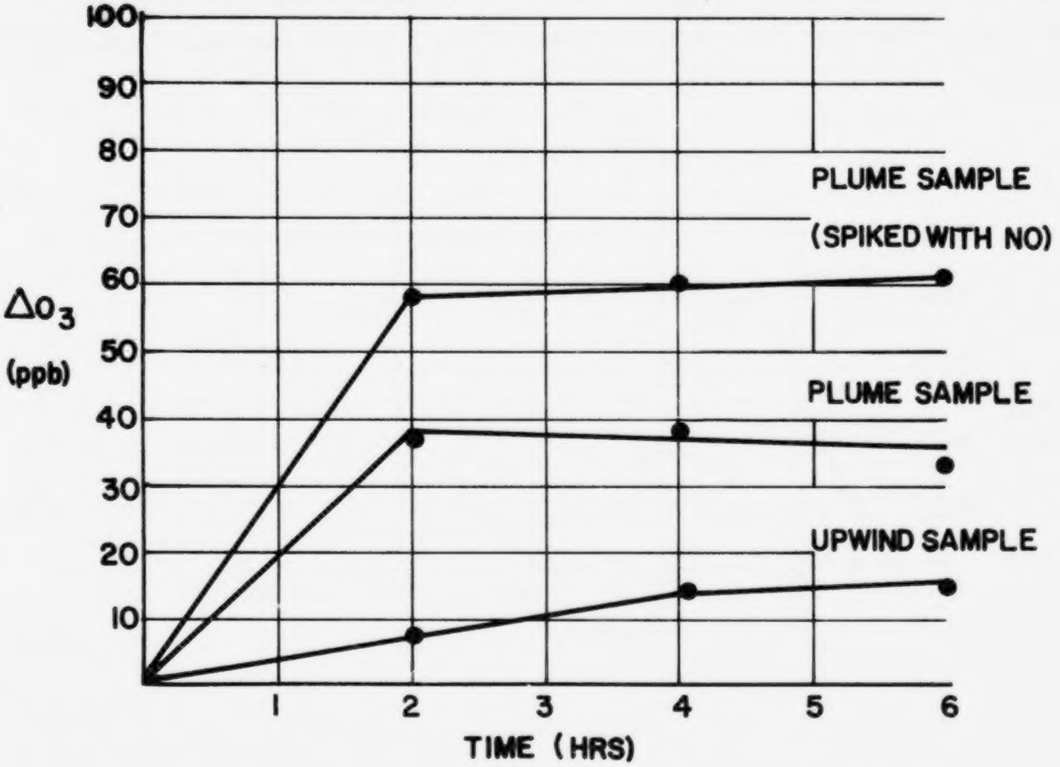

Figure 8. Data obtained from natural sunlight bag irradiation on September 18, 1975.

Examination of all irradiation experiments conducted during the study for which hydrocarbon data is available indicates that the NMTHC/NO_x ratio is a critical factor affecting ozone production. Figure 9 is a plot of peak ozone production for all in-plume samples versus NMTHC/NO_x ratios. These data suggest that a NMTHC/NO_x ratio of approximately 15 is the optimum condition for maximum ozone formation. This result agrees closely with a subsequent study by Washington State University examining the effect of NMTHC/NO_x ratios on ozone generation in power plant plumes.[16] The difference in maximum ozone production noted previously in Figure 8 between the two samples representative of Exxon emissions appears to be caused primarily by the lowering of the NMTHC/NO_x ratio in the bag spiked with NO from approximately 28 (for the unspiked sample) to 19.

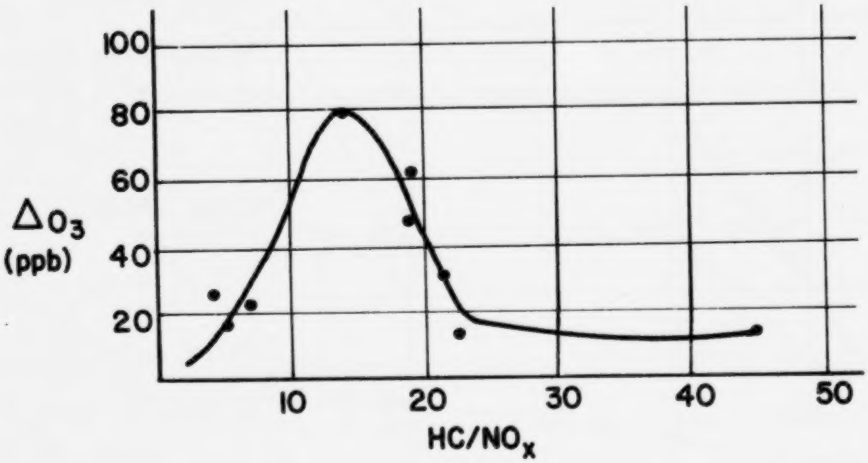

Figure 9. Observed effect of HC/NO_x ratios on ozone formation in captive air irradiation experiments.

The bag irradiation studies also suggest that the concentration of NMTHC affects peak ozone production, although to a lesser degree. For example, at a constant NMTHC/NO_x ratio of 21 increasing hydrocarbon levels from 480 ppb

(9/16/75) to 740 ppb (9/17/75) caused an 8 ppb increase in measured maximum ozone values. Similarily, going from 740 ppb (9/17/75) to 900 ppb (9/18/75) NMTHC at a constant NMTHC/NO_x ratio of 19 resulted in a 14 ppb increase in peak ozone levels (see Table 7). The observed dependence of in-plume ozone production on NMTHC/NO_x ratios and NMTHC concentrations is consistent with indoor smog chamber experiments conducted by several investigators.[17,18]

In addition to the effects of NMTHC/NO_x ratios and absolute hydrocarbon levels on ozone generation, the bag irradiation studies also suggest that ozone levels in excess of 70 ppb can, under certain conditions, be produced solely from atmospheric refinery emissions. The data indicate that even though Exxon emissions consist primarily of saturated hydrocarbons, ozone levels substantially above those expected from typical ambient background air can be generated during irradiation times characteristic of one day (6 to 8 hours). This is not to imply that violations of the National Ambient Air Quality Standard (NAAQS) for oxidants would necessarily result from the Exxon plume alone, but rather that the airborne discharges arising from the Exxon refinery have the potential to produce photochemical ozone. The amount of ozone actually generated within the plume boundaries, if any, would depend on a great number of intervening variables, including complex interactions between meteorological and topographical factors.

In point of fact, no plume related ozone concentrations in excess of ambient background levels were observed during the course of this monitoring program. Indeed, for the most part ozone concentrations within the Exxon plume boundaries were found to be lower than surrounding background levels due to scavenging by nitric oxide. This apparent contradiction with the aforementioned photochemical potential indicated by the irradiation studies has several possible explanations. The importance of NMTHC/NO_x ratios and NMTHC concentrations has already been discussed and it is possible that one or both of these act as inhibiting factors. It is also possible that persistently high wind speeds through the Carquinez Strait and into the delta region did not permit sufficient time for measurable ozone production. Typical wind speeds in this area (15 mph) meant that only about 30 minutes were required for an air parcel to be transported eight miles, the maximum distance it was possible to track the Exxon plume. WSU captive air irradiation studies and smog chamber experiments by other researchers[19] have shown that very little photochemical ozone is produced during a 30-minute irradiation period when primarily saturated hydrocarbons are involved. Results of the on site bag irradiation experiments indicate a minimum of one hour was required for peak ozone production.

Although no plume related ozone was observed during the Exxon monitoring program, definite ozone buildup did occur between 15 to 30 miles downwind of the Exxon refinery in the delta region of the Sacramento and San Joaquin Rivers. Ozone formation and transport were examined using a two-stage flight path. First, a short upwind segment was flown to establish the pollutant burden of the incoming air mass, and then a longer downwind portion was accomplished in order to measure ozone concentrations at varying distances from the refinery. Figure 10 depicts ozone values measured on this type of flight during the afternoon on September 14, 1975 (1305 - 1505 PDT). A strong temperature inversion between 2000 and 3000 feet AGL was evident throughout the afternoon and pibal observations indicated a distinct wind shear above this stable layer. All available evidence suggests that observed ozone levels resulted from photochemical processes confined to the mixing layer.

As was the case throughout the September 8-22 sampling period, relatively clean air was observed upwind of Benicia in the general area of San Pablo Bay. Hydrocarbon concentrations in the C_2-C_6 weight range were consistently below 20 $\mu g/m^3$ over San Pablo Bay and ozone levels were normally between 35-45 ppb. As shown in Figure 10, ozone concentrations increased gradually as the aircraft moved inland reaching a high of 88 ppb north of Stockton. This ozone buildup in the delta region to the east of Benicia was routinely observed on all flights into the region. More detailed ozone values as the plane moved downwind from the Exxon refinery into the delta region on the 14th are presented in Figure 11.

Hydrocarbon measurements made during the flights on September 14 also illustrate the pollutant buildup eastward from San Pablo Bay along the Carquinez Strait - Suisun Bay channel. Individual C_2-C_6 hydrocarbon identification for selected samples is given in Table 8. Light hydrocarbon levels

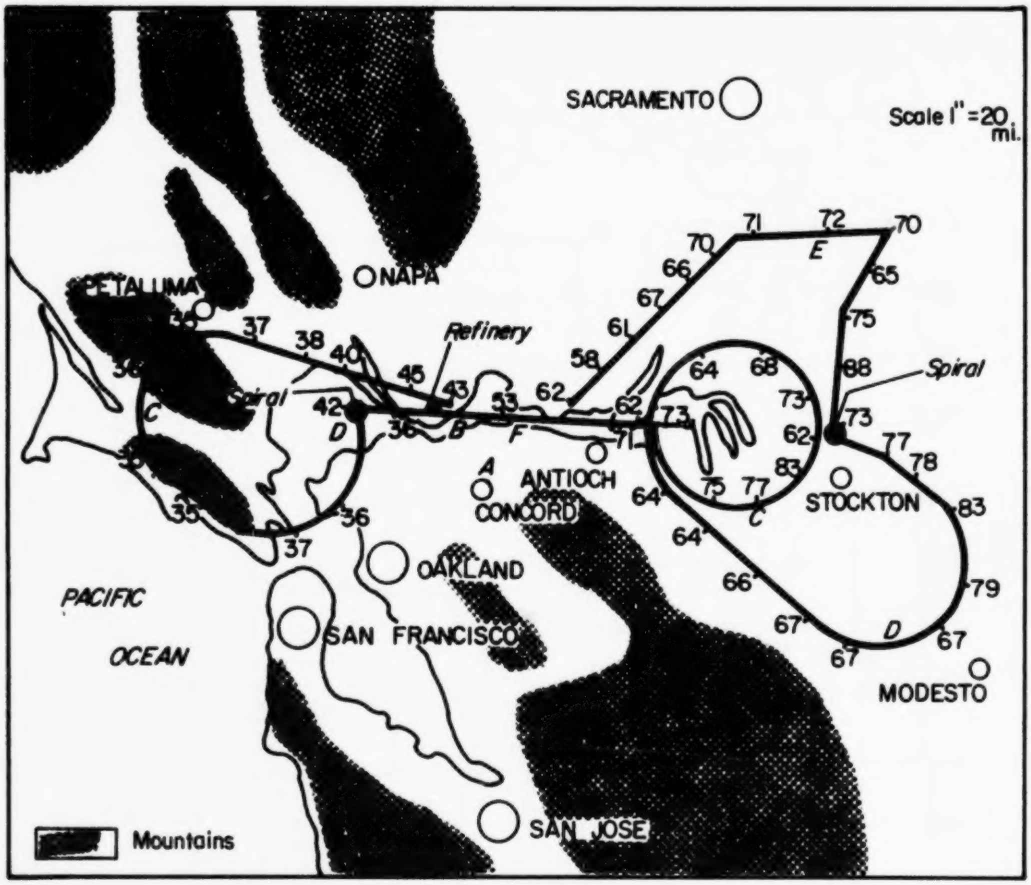
SACRAMENTO
Scale 1" = 20 mi.
PETALUMA
NAPA
Refinery
Spiral
Spiral
ANTIOCH
CONCORD
STOCKTON
OAKLAND
SAN FRANCISCO
MODESTO
SAN JOSE
PACIFIC OCEAN
Mountains
A
B
C
D
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Figure 10. Ozone concentrations measured during the flights on September 14, 1975.

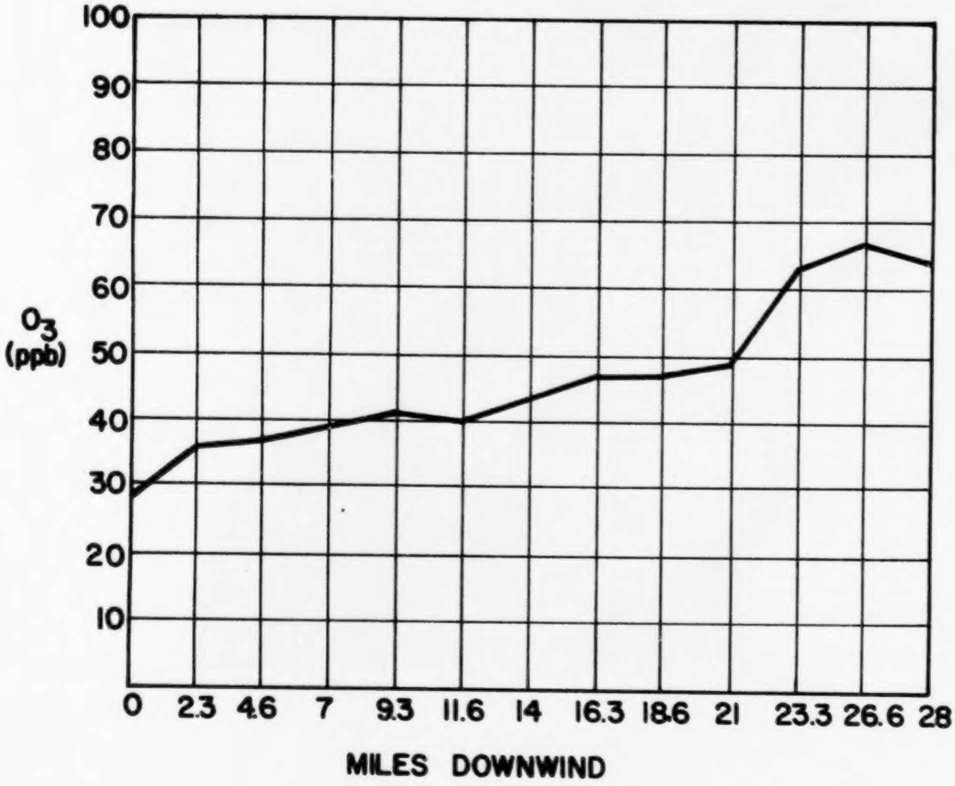

Figure 11. Ozone concentrations downwind of the Exxon refinery on September 14, 1975.

obviously increase from less than 10 μg/m^3 near Napa and over the coastal mountains to almost 60 μg/m^3 near Pittsburgh in the river delta region. Similar values were recorded for all flights of this type on which hydrocarbon samples were collected.

The observed increase of hydrocarbon concentrations inland along the channel suggests the cumulative contribution of the many refineries and other industrial plants located between Richmond and Antioch. This conclusion is supported by sulfur hexafluoride (SF_6) tracer studies performed in this portion of the San Francisco Bay Area by Lamb and Shair of the California Institute of Technology.[19] Their research showed that pollutants can be transported from as far west as Pinole (just east of Richmond) inland through the Carquinez Strait and across the delta region. Therefore, it seems likely that the ozone buildup characteristically measured in the delta region west of Antioch results from precursor emissions originating upwind along the heavily industrialized channel between Richmond and Antioch. Although the effluent from the Exxon refinery at Benicia undoubtedly contributes to the airborne pollutants transported into the delta region, interferences from other anthropogenic emission sources precluded attempts to isolate the Exxon plume and quantify its effect on observed photochemical ozone production.

TABLE 8. SELECTED LIGHT HYDROCARBON MEASUREMENTS DURING FLIGHTS ON SEPTEMBER 14, 1975

	Concentration ($\mu g/m^3$)						
	A-1	A-2	A-3	A-4	A-5	A-6	A-7
ethane	3.5	4.0	3.5	4.0	5.5	6.0	6.5
ethylene	*	*	*	1.5	1.0	1.0	1.5
acetylene	*	*	*	1.0	1.0	1.0	1.0
propane	1.5	2.0	1.5	2.0	4.5	7.5	5.5
propene	*	*	*	*	1.0	*	1.0
i-butane	*	*	*	0.5	0.3	4.0	6.5
n-butane	*	1.0	*	1.5	5.0	6.0	15.0
1-butene	*	*	*	*	*	*	*
i-butene	*	*	*	*	*	*	1.0
t-2-butene	*	*	*	*	*	*	*
propyne	*	*	*	*	*	*	*
c-2-butene	*	*	*	*	*	*	*
i-pentane	*	1.0	*	2.5	5.0	7.5	9.0
n-pentane	*	1.0	*	1.0	2.5	3.0	5.5
cyclopentane	*	*	*	*	*	*	*
1-pentene	*	*	*	*	*	*	*
i-hexane	*	*	*	-	1.5	-	2.0
3-m-pentane	*	*	*	-	1.0	-	1.5
n-hexane	*	*	*	-	1.5	-	2.0
Total $\mu g/m^3$	5.0	9.0	5.0	14.0	32.0	36.0	58.0
Total ppm C	0.01	0.01	0.01	0.02	0.05	0.06	0.09

SAMPLE LOCATION

A-1 Over WSU trailer at 11,000 ft. MSL.
A-2 Over radio towers near Napa VOR at 1,200 ft. MSL.
A-3 Over coastal mountains NW of San Francisco at 1,700 ft. MSL
A-4 Over San Pablo Bay at 1,000 ft. MSL.
A-5 Just downwind of Standard Oil Refinery (Richmond) at 1,000 ft. MSL.
A-6 Over Carquinez Strait approximately 3 miles west of Benicia at 1,000 ft. MSL.
A-7 Near Pittsburgh at 1,000 ft. MSL.

* $< 0.5\ \mu g/m^3$ - missing data

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APPENDIX A

This section presents pollutant concentrations and meteorological parameters recorded at the WSU field laboratory for the entire September 8-22 monitoring program. All of the pibal observations made during the study are also included. Hourly averages for O_3, NO, NO_2, NMTHC, CO, CH_4, CH_3CCl_3, wind speed, wind direction, gustiness (an indicator of turbulence intensity), temperature, and solar radiation are given in tabular form. In addition, hourly plots of NO, NO_2, CO, CCl_4, $CFCl_3$, O_3 and wind direction are provided for each day. A summary of upper level winds to approximately 6000 feet MSL is included for each of the pilot balloon releases.

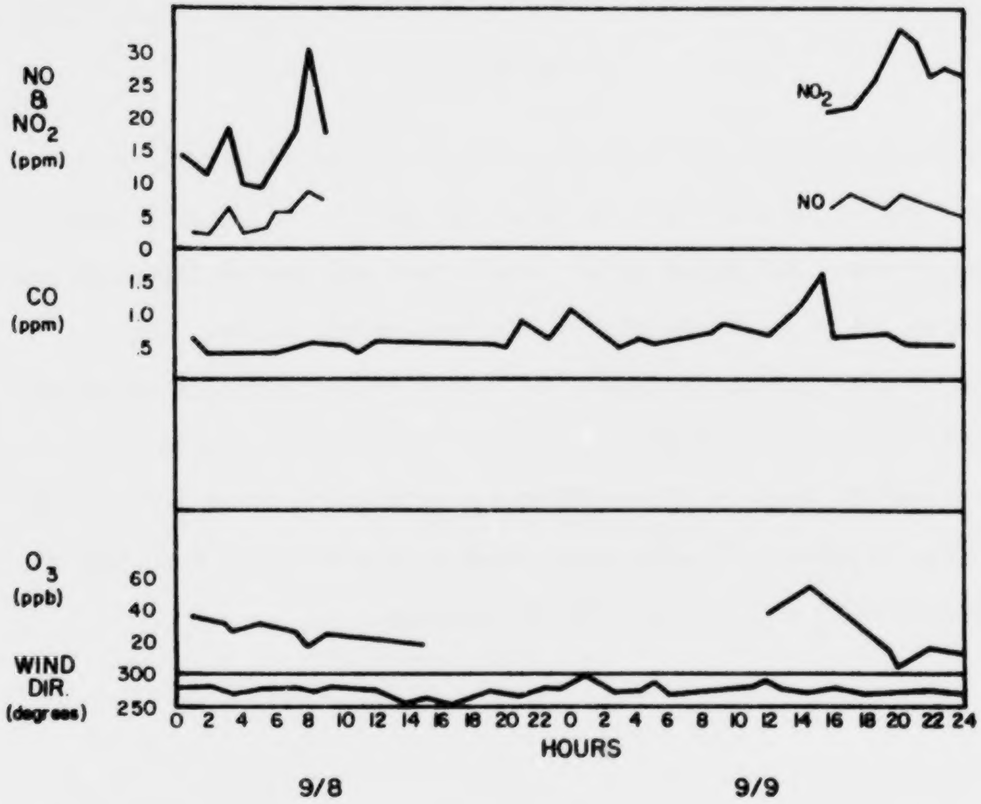


Figure A1. Plot of selected data from the WSU trailer on September 8 & 9, 1975.

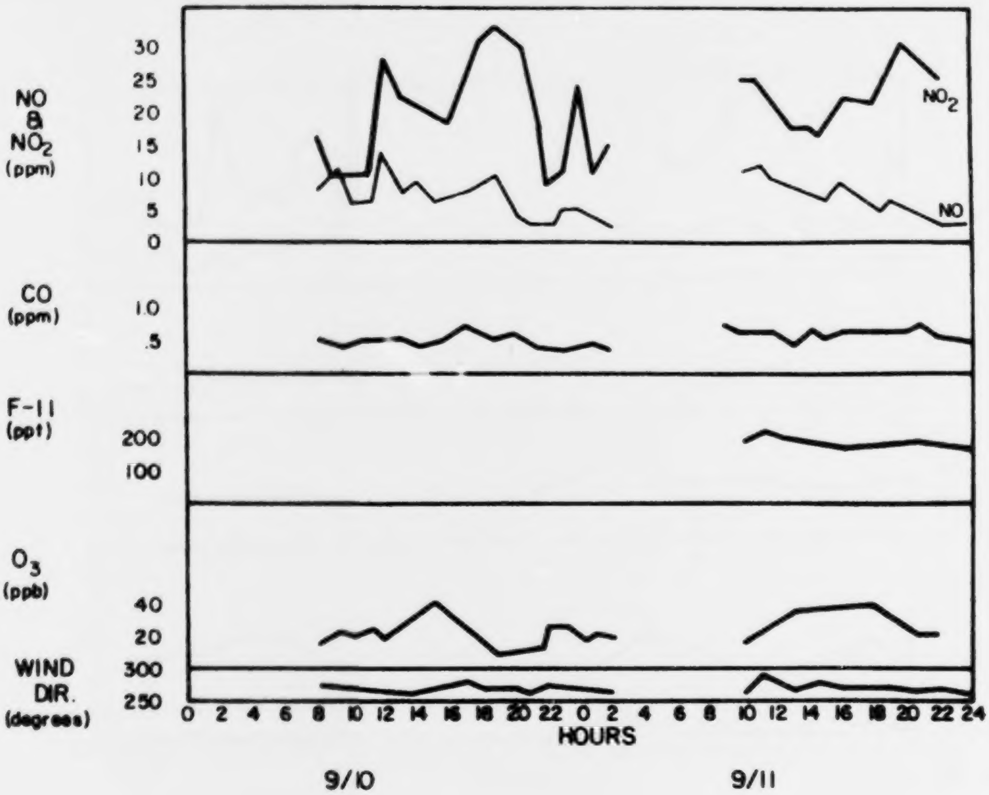


Figure A2. Plot of selected data from the WSU trailer on September 10 & 11, 1975.

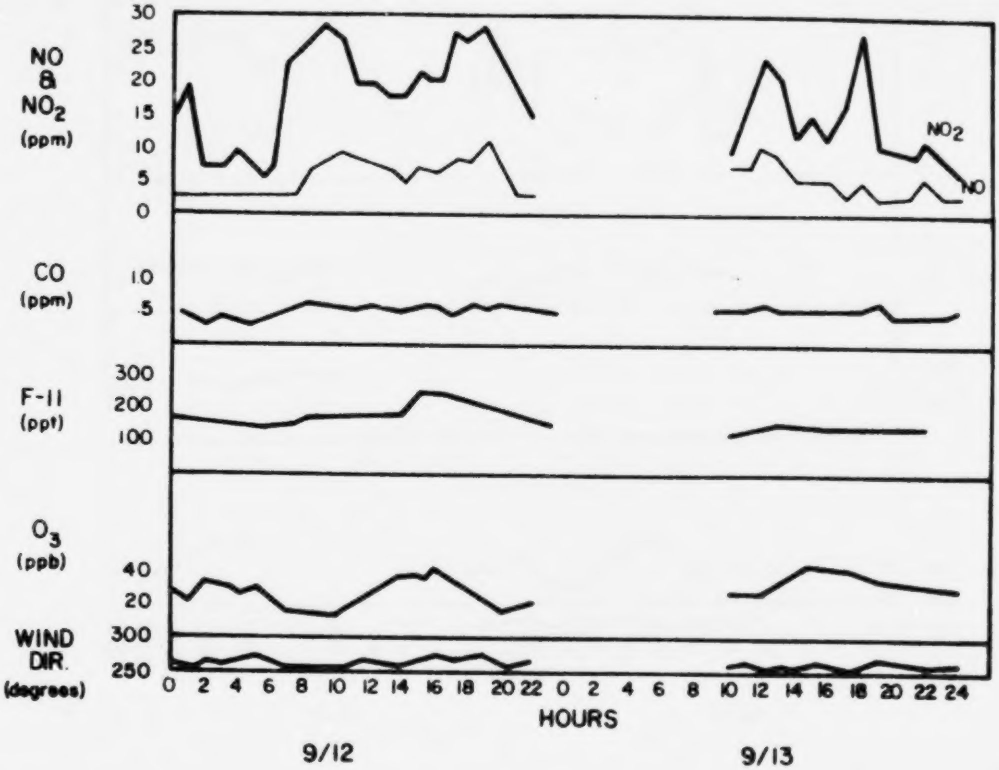


Figure A3. Plot of selected data from the WSU trailer on September 12 & 13, 1975.

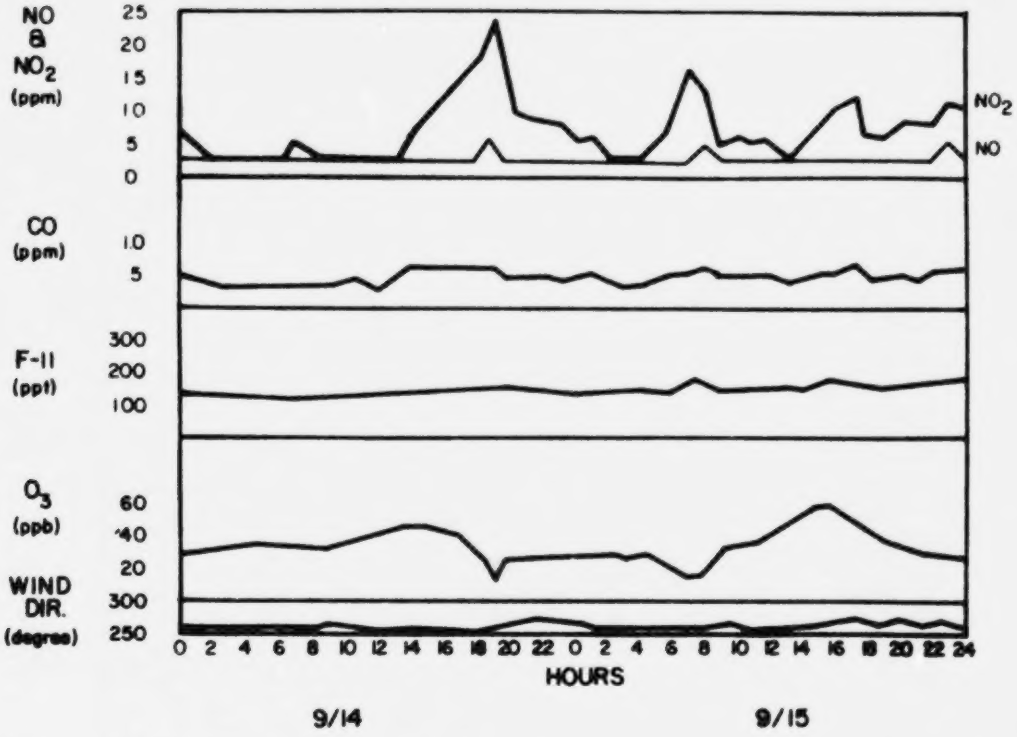


Figure A4. Plot of selected data from the WSU trailer on September 14 & 15, 1975.

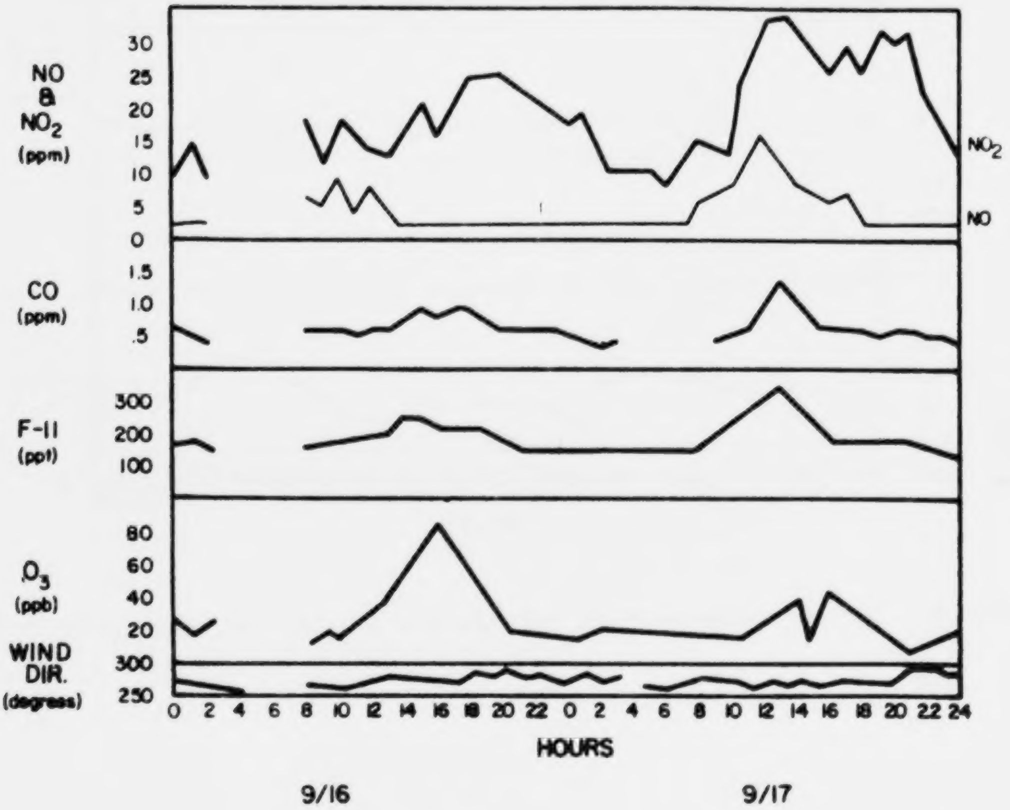


Figure A5. Plot of selected data from the WSU trailer on September 16 & 17, 1975.

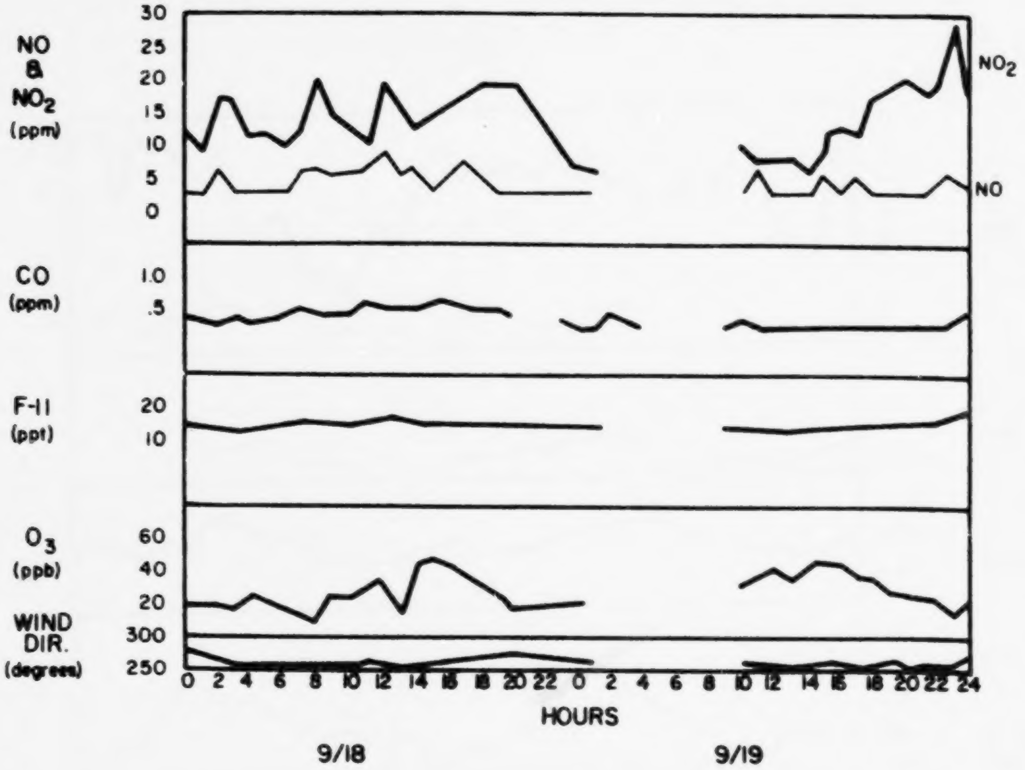


Figure A6. Plot of selected data from the WSU trailer on September 18 & 19, 1975.

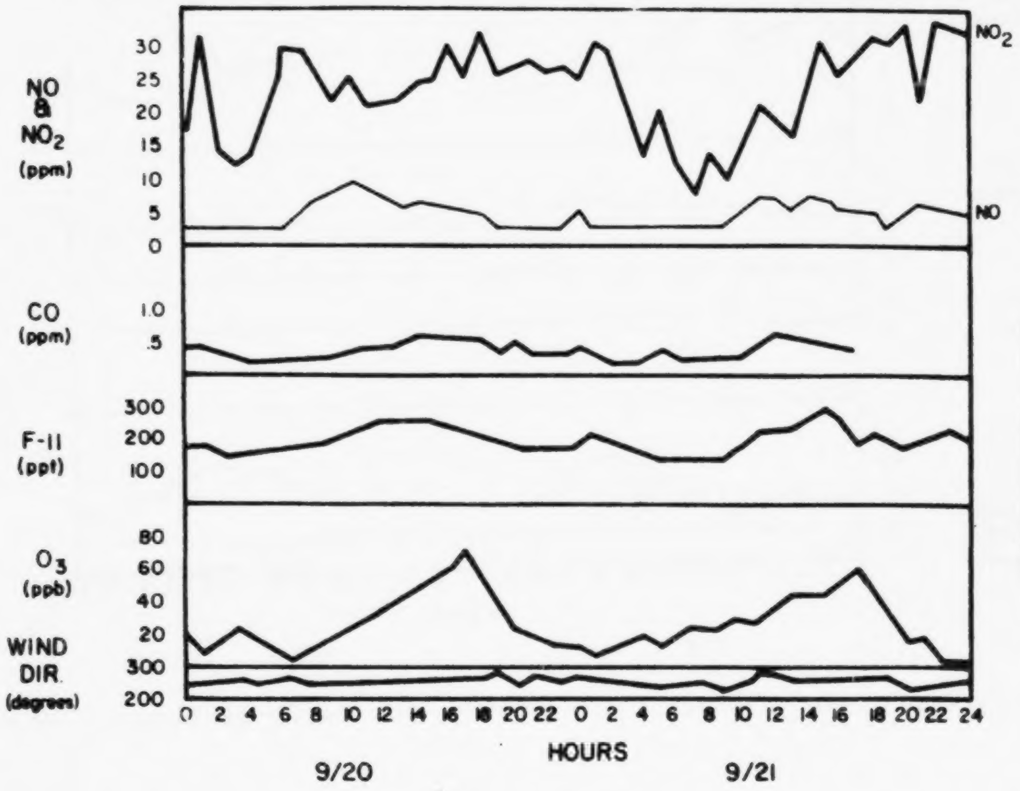


Figure A7. Plot of selected data from the WSU trailer on September 20 & 21, 1975.

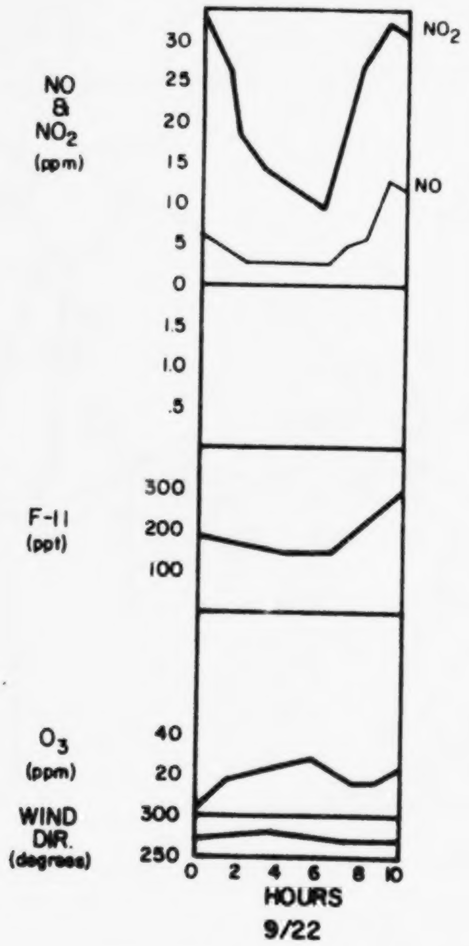
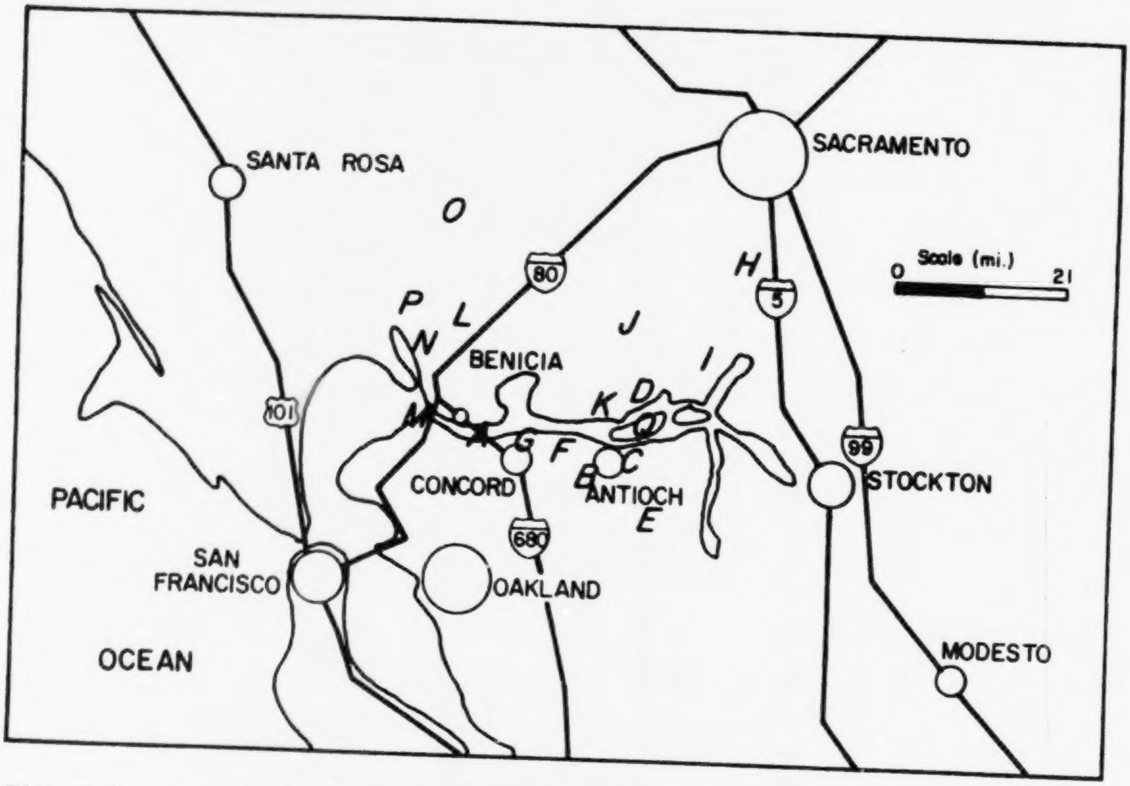


Figure A8. Plot of selected data from the WSU trailer on September 22, 1975.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ANTIOCH
STOCKTON
PACIFIC
E
680
SAN FRANCISCO
OAKLAND
OCEAN
MODESTO

Figure A9. Location of pibal releases during the monitoring program, September 8 - 22, 1975.

A-WSU trailer
B-Antioch #1
C-Antioch #2
D-Emmaton
E-Brentwood
F-Pittsburg
G-Port Chicago
H-Hood

I-Poverty Rd.
J-Dozier & Hwy 113
K-Collinsville
L-Rockville
M-Crockett
N-Intersection #23/#12
O-Rutherford
P-Sonoma
Q-Grizzly Island

TABLE A1. GROUND LEVEL DATA COLLECTED AT THE WSU TRAILER SITE ON SEPTEMBER 8, 1975

	GAS DATA								MET. DATA					
Time	O_3	NO	NO_2	NMTHC	CO	CH_4	$CFCl_3$	CCl_4	WS	WD	σ_θ	TMP	DP	RAD
hr	ppb	ppb	ppb	ppmC	ppm	ppm	ppt	ppt	mph	deg	deg	°F	°F	mLy
0100	35	<5	13	.1	.6	1.6	--	--	15	278	10	56	--	0
0200	33	<5	12	.1	.4	1.6	--	--	15	283	8	56	--	0
0300	27	6	18	.2	.4	1.6	--	--	22	272	7	56	--	0
0400	31	<5	10	<.1	.4	1.6	--	--	22	271	6	56	--	0
0500	31	<5	9	<.1	.4	1.6	--	--	20	278	5	56	--	0
0600	29	6	13	.1	.4	1.6	--	--	18	276	5	56	--	0
0700	24	6	18	.1	.5	1.6	--	--	18	278	7	56	--	0
0800	15	9	30	.2	.5	1.6	--	--	20	272	6	57	--	49
0900	24	7	18	.2	.5	1.6	--	--	23	283	--	--	--	--
1000	24	--	--	.1	.5	1.6	--	--	20	282	7	60	--	443
1100	23	--	--	.2	.4	1.6	--	--	20	274	7	61	--	357
1200	23	--	--	.2	.6	1.6	--	--	20	273	7	61	--	236
1300	22	--	--	.3	.6	1.6	--	--	23	265	5	61	--	291
1400	20	--	--	.2	.6	1.6	--	--	17	245	6	64	--	345
1500	20	--	--	.1	.6	1.6	--	--	23	260	6	61	--	260
1600	--	--	--	.2	.6	1.6	--	--	18	256	6	63	--	301
1700	--	--	--	.4	.6	1.6	--	--	18	245	3	62	--	169
1800	--	--	--	.1	.6	1.6	--	--	13	260	8	61	--	80
1900	--	--	--	.1	.6	1.6	--	--	12	268	13	62	--	17
2000	--	--	--	.1	.5	1.6	--	--	17	266	7	62	--	0
2100	--	--	--	.2	.9	1.6	--	--	13	267	11	62	--	0
2200	--	--	--	.3	.6	1.6	--	--	12	277	8	63	--	0
2300	--	--	--	.1	.6	1.6	--	--	18	276	6	63	--	0
2400	--	--	--	.3	1.1	1.7	--	--	18	284	7	62	--	0

TABLE A2. GROUND LEVEL DATA COLLECTED AT THE WSU TRAILER SITE ON SEPTEMBER 9, 1975

	GAS DATA								MET. DATA					
Time hr	O_3 ppb	NO ppb	NO_2 ppb	NMTHC ppmC	CO ppm	CH_4 ppm	$CFCl_3$ ppt	CCl_4 ppt	WS mph	WD deg	σ_θ deg	TMP °F	DP °F	RAD mLy
0100	--	--	--	.1	.8	1.6	--	--	13	298	8	62	--	0
0200	--	--	--	.1	.6	1.6	--	--	13	279	8	61	--	0
0300	--	--	--	.1	.5	1.6	--	--	12	273	7	60	--	0
0400	--	--	--	.1	.6	1.6	--	--	15	275	8	60	--	0
0500	--	--	--	.2	.5	1.6	--	--	13	287	7	59	--	0
0600	--	--	--	.1	.6	1.6	--	--	13	264	7	58	--	0
0700	--	--	--	<.1	.6	1.6	--	--	13	270	7	58	--	0
0800	--	--	--	.2	.6	1.6	--	--	13	276	7	60	--	61
0900	--	--	--	.1	.8	1.7	--	--	15	275	10	61	--	188
1000	--	--	--	.2	.8	1.7	--	--	18	270	10	62	--	415
1100	--	--	--	.1	.8	1.7	--	--	17	280	10	67	--	1275
1200	37	--	--	<.1	.6	1.7	--	--	18	290	11	70	--	1261
1300	43	--	--	.1	.8	1.7	--	--	22	275	12	73	--	1301
1400	50	--	--	.3	1.1	1.6	--	--	20	270	12	74	--	1223
1500	49	--	--	.1	1.7	1.6	--	--	18	272	12	75	--	1158
1600	42	6	21	.1	.6	1.7	--	--	18	280	10	78	--	972
1700	38	8	21	.2	.6	1.6	--	--	18	276	11	75	--	728
1800	28	7	23	.1	.6	1.6	--	--	22	265	5	71	--	384
1900	18	6	28	.1	.7	1.6	--	--	18	265	11	66	--	110
2000	<5	8	44	.4	.6	1.7	--	--	18	268	5	62	--	0
2100	5	7	35	.3	.5	1.7	--	--	15	270	5	61	--	0
2200	13	6	26	.2	.5	1.7	--	--	17	276	8	60	--	0
2300	11	5	27	.1	.5	1.6	--	--	17	273	6	58	--	0
2400	12	<5	26	--	--	--	--	--	20	270	6	58	--	0

TABLE A3. GROUND LEVEL DATA COLLECTED AT THE WSU TRAILER SITE ON SEPTEMBER 10, 1975

	GAS DATA								MET. DATA					
Time hr	O_3 ppb	NO ppb	NO_2 ppb	NMTHC ppmC	CO ppm	CH_4 ppm	$CFCl_3$ ppt	CCl_4 ppt	WS mph	WD deg	σ_θ deg	TMP °F	DP °F	RAD mLy
0100	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0200	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0300	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0400	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0500	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0600	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0700	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0800	15	8	16	<.1	.5	1.7	--	--	17	273	7	57	--	83
0900	21	11	10	<.1	.4	1.7	--	--	13	272	7	58	--	310
1000	20	6	10	.1	.4	1.6	--	--	17	270	7	61	--	490
1100	22	6	11	.2	.5	1.7	--	--	18	265	7	62	--	618
1200	18	14	28	.1	.5	1.7	--	--	17	261	9	65	--	1021
1300	29	8	22	.1	.5	1.7	--	--	17	260	8	67	--	842
1400	35	9	21	<.1	.4	1.7	--	--	18	260	9	71	54	1252
1500	39	6	19	<.1	.4	1.7	--	--	17	264	8	72	53	787
1600	36	6	18	<.1	.5	1.7	--	--	18	268	7	71	53	471
1700	26	7	26	.1	.7	1.6	--	--	22	279	7	68	54	198
1800	18	9	32	.2	.6	1.6	--	--	17	267	7	66	54	100
1900	7	10	42	.1	.5	1.7	--	--	15	267	6	65	54	38
2000	11	5	32	<.1	.6	1.7	--	--	13	272	6	63	53	0
2100	11	<5	27	<.1	.4	1.7	--	--	13	261	6	62	54	0
2200	26	<5	9	.1	.4	1.6	--	--	17	272	6	62	52	0
2300	23	5	11	<.1	.3	1.6	--	--	13	266	6	61	53	0
2400	14	5	24	.1	.4	1.7	--	--	13	265	6	61	54	0

TABLE A4. GROUND LEVEL DATA COLLECTED AT THE WSU TRAILER SITE ON SEPTEMBER 11, 1975

	GAS DATA								MET. DATA					
Time hr	O_3 ppb	NO ppb	NO_2 ppb	NMTHC ppmC	CO ppm	CH_4 ppm	$CFCl_3$ ppt	CCl_4 ppt	WS mph	WD deg	σ_θ deg	TMP °F	DP °F	RAD mLy
0100	22	<5	11	<.1	.4	1.7	160	125	13	266	7	59	53	0
0200	16	<5	15	<.1	.3	1.7	156	135	12	264	6	59	52	0
0300	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0400	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0500	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0600	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0700	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0800	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0900	--	--	--	<.1	.7	1.7	--	--	--	--	--	--	--	--
1000	14	11	25	<.1	.6	1.7	190	125	17	260	6	60	52	520
1100	22	12	25	.1	.6	1.7	213	125	18	287	8	65	53	1074
1200	27	10	21	.2	.6	1.6	209	125	18	274	9	66	54	1233
1300	35	9	17	.1	.4	1.6	201	135	20	266	8	69	54	1305
1400	36	7	17	.1	.6	1.7	190	135	18	275	8	72	54	1261
1500	38	6	16	.1	.5	1.6	175	135	17	275	7	74	53	1126
1600	37	9	22	.1	.6	1.7	179	135	20	268	7	75	53	915
1700	37	7	21	.1	.6	1.7	179	135	18	269	7	74	53	648
1800	38	5	21	.2	.6	1.6	179	135	17	271	7	72	52	361
1900	30	6	26	.2	.6	1.6	175	145	17	265	6	67	52	92
2000	19	5	31	.1	.6	1.7	186	135	17	266	7	63	52	0
2100	20	<5	27	.1	.7	1.7	190	135	15	265	7	60	52	0
2200	20	<5	25	<.1	.5	1.7	179	135	18	269	6	59	52	0
2300	--	--	--	<.1	.5	1.7	175	125	--	--	--	--	--	0
2400	29	<5	13	<.1	.4	1.6	163	145	20	262	6	57	52	0

TABLE A5. GROUND LEVEL DATA COLLECTED AT THE WSU TRAILER SITE ON SEPTEMBER 12, 1975

	GAS DATA								MET. DATA					
Time hr	O_3 ppb	NO ppb	NO_2 ppb	NMTHC ppmC	CO ppm	CH_4 ppm	$CFCl_3$ ppt	CCl_4 ppt	WS mph	WD deg	σ_θ deg	TMP °F	DP °F	RAD mLy
0100	22	<5	19	.1	.4	1.6	160	145	18	251	5	58	52	0
0200	30	<5	7	<.1	.3	1.6	156	135	18	267	5	57	51	0
0300	30	<5	7	.1	.4	1.7	152	135	15	258	7	57	51	0
0400	26	<5	10	<.1	.3	1.6	144	124	15	254	6	57	51	0
0500	29	<5	6	<.1	.3	1.6	140	134	15	268	5	56	50	0
0600	27	<5	7	<.1	.4	1.6	140	134	15	266	6	56	50	0
0700	14	<5	23	<.1	.5	1.7	151	134	15	250	5	57	51	0
0800	14	6	25	<.1	.6	1.8	165	124	17	247	5	57	51	59
0900	14	7	28	.1	.5	1.7	175	134	17	251	6	58	51	195
1000	15	9	27	.1	.5	1.7	172	134	17	250	7	59	51	433
1100	20	9	21	.1	.5	1.7	--	--	18	263	7	62	51	941
1200	27	8	19	.1	.6	1.7	179	134	20	266	7	64	51	1210
1300	32	7	17	.1	.5	1.5	168	134	18	254	7	66	52	1272
1400	37	5	18	<.1	.5	1.6	179	134	20	257	7	71	52	1250
1500	37	7	21	<.1	.6	1.6	249	124	18	260	8	72	53	1121
1600	41	6	20	<.1	.6	1.7	256	134	18	276	8	74	53	912
1700	35	8	27	<.1	.4	1.6	245	134	20	266	7	74	53	633
1800	31	8	26	.2	.6	1.6	221	134	18	272	6	71	53	362
1900	21	11	28	<.1	.5	1.6	196	134	18	272	7	66	52	98
2000	15	6	24	<.1	.6	1.6	172	134	22	255	6	61	52	0
2100	19	<5	18	<.1	.5	1.6	161	134	18	261	6	60	52	0
2200	23	<5	14	<.1	.5	1.5	158	134	17	266	7	60	52	0
2300	--	--	--	<.1	.5	1.5	154	124	--	--	7	59	52	0
2400	--	--	--	--	--	--	--	--	--	--	--	--	--	--

TABLE A6. GROUND LEVEL DATA COLLECTED AT THE WSU TRAILER SITE ON SEPTEMBER 13, 1975

	GAS	DATA							MET.	DATA				
Time hr	O_3 ppb	NO ppb	NO_2 ppb	NMTHC ppmC	CO ppm	CH_4 ppm	$CFCl_3$ ppt	CCl_4 ppt	WS mph	WD deg	σ_θ deg	TMP °F	DP °F	RAD mLy
0100	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0200	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0300	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0400	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0500	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0600	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0700	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0800	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0900	--	--	--	<.1	.5	1.5	--	--	--	--	--			--
1000	28	7	9	<.1	.5	1.6	118	116	15	257	7	60	52	239
1100	25	7	18	.1	.5	1.6	138	116	18	266	9	64	53	617
1200	--	10	23	.1	.6	1.6	157	116	18	255	8	65	53	1223
1300	33	8	20	.1	.5	1.8	157	116	18	262	9	67	52	1273
1400	42	5	12	<.1	.5	1.7	147	116	18	256	7	69	53	1263
1500	45	5	14	<.1	.5	1.7	150	116	22	262	7	71	53	1135
1600	46	5	11	<.1	.5	1.6	144	116	18	258	8	72	53	915
1700	43	<5	15	.1	.5	1.6	144	116	18	257	7	72	53	621
1800	36	5	27	.1	.5	1.6	154	116	20	255	6	69	53	352
1900	33	<5	11	<.1	.6	1.6	138	116	17	269	6	65	52	73
2000	31	<5	10	<.1	.4	1.6	144	116	13	267	8	62	52	0
2100	30	<5	8	<.1	.4	1.6	144	116	17	264	5	60	51	0
2200	29	5	11	<.1	.4	1.6	138	116	20	257	5	60	51	0
2300	29	<5	8	<.1	.4	1.6	--	--	20	259	5	60	51	0
2400	31	<5	7	<.1	.5	1.6	131	116	18	261	6	60	51	0

TABLE A7. GROUND LEVEL DATA COLLECTED AT THE WSU TRAILER SITE ON SEPTEMBER 14, 1975

	GAS DATA								MET. DATA					
Time	O_3	NO	NO_2	NMTHC	CO	CH_4	$CFCl_3$	CCl_4	WS	WD	σ_θ	TMP	DP	RAD
hr	ppb	ppb	ppb	ppmC	ppm	ppm	ppt	ppt	mph	deg	deg	°F	°F	mLy
0100	30	<5	5	<.1	.4	1.6	128	116	17	256	6	60	51	0
0200	33	<5	<5	<.1	.3	1.6	128	116	15	256	6	60	50	0
0300	36	<5	<5	<.1	.3	1.6	125	116	17	256	6	60	50	0
0400	36	<5	<5	<.1	.3	1.6	125	116	15	254	6	59	50	0
0500	34	<5	<5	<.1	.3	1.7	128	124	12	261	6	59	50	0
0600	34	<5	<5	<.1	.3	1.6	128	124	12	257	6	60	50	0
0700	32	<5	5	<.1	.3	1.6	128	116	12	262	6	60	50	0
0800	33	<5	<5	<.1	.3	1.6	128	116	13	260	7	60	50	130
0900	35	<5	<5	<.1	.3	1.6	131	116	15	267	8	62	50	383
1000	36	<5	<5	<.1	.4	1.6	131	124	17	258	9	65	50	750
1100	37	<5	<5	<.1	.4	1.5	128	124	15	255	7	66	50	1069
1200	40	<5	<5	<.1	.3	1.6	131	124	18	256	7	68	50	1218
1300	45	<5	<5	.2	.4	1.6	138	116	18	248	7	71	51	1274
1400	44	<5	7	.1	.6	1.6	141	124	17	259	8	73	51	1240
1500	44	<5	9	.2	.6	1.6	141	124	17	252	9	74	51	1062
1600	41	<5	12	.1	.6	1.6	141	124	17	255	8	75	51	873
1700	37	<5	14	.1	.6	1.6	150	124	17	248	7	74	51	592
1800	28	<5	17	.1	.6	1.6	150	124	18	249	6	70	51	325
1900	16	5	23	<.1	.6	1.7	150	124	17	255	6	67	51	71
2000	25	<5	11	<.1	.4	1.6	138	124	13	266	6	64	51	0
2100	27	<5	8	<.1	.4	1.6	138	124	17	269	6	61	49	0
2200	26	<5	8	<.1	.5	1.6	141	124	15	268	6	60	49	0
2300	27	<5	8	<.1	.4	1.6	138	124	18	264	5	59	49	0
2400	27	<5	5	<.1	.4	1.6	138	124	20	271	6	59	50	0

TABLE A8. GROUND LEVEL DATA COLLECTED AT THE WSU TRAILER SITE ON SEPTEMBER 15, 1975

	GAS DATA								MET. DATA					
Time hr	O_3 ppb	NO ppb	NO_2 ppb	NMTHC ppmC	CO ppm	CH_4 ppm	$CFCl_3$ ppt	CCl_4 ppt	WS mph	WD deg	σ_θ deg	TMP °F	DP °F	RAD mLy
0100	26	<5	6	<.1	.5	1.7	134	124	17	256	5	58	50	0
0200	28	<5	<5	<.1	.4	1.7	138	124	13	254	5	58	50	0
0300	24	<5	5	<.1	.3	1.8	141	124	13	251	5	56	50	0
0400	27	<5	<5	<.1	.3	1.7	131	124	12	250	4	57	50	0
0500	29	<5	5	<.1	.4	1.5	131	124	13	251	5	57	50	0
0600	16	<5	11	.1	.5	1.7	147	124	8	255	5	55	49	0
0700	13	<5	16	<.1	.5	1.7	170	124	10	254	6	57	50	0
0800	23	5	13	<.1	.6	1.6	154	124	13	259	6	59	50	211
0900	33	<5	5	<.1	.5	1.6	147	124	17	265	8	62	50	518
1000	34	<5	6	<.1	.5	1.6	154	124	17	261	8	65	50	795
1100	37	<5	5	<.1	.5	1.6	150	124	15	252	8	67	51	1047
1200	46	<5	5	<.1	.5	1.6	147	124	15	255	9	70	50	1218
1300	51	<5	<5	<.1	.4	1.6	144	124	12	252	10	73	50	1292
1400	--	<5	5	<.1	.4	1.6	147	124	13	254	7	76	49	1270
1500	--	<5	9	<.1	.5	1.6	163	124	15	265	8	78	50	1123
1600	58	<5	10	.1	.5	1.6	160	133	17	266	8	78	49	894
1700	47	<5	12	.1	.6	1.7	166	133	17	268	8	76	49	595
1800	40	<5	6	<.1	.4	1.6	147	124	17	261	7	72	48	343
1900	34	<5	6	<.1	.4	1.6	147	124	17	272	6	68	48	82
2000	32	<5	8	<.1	.5	1.6	154	124	13	270	6	64	48	0
2100	30	<5	8	<.1	.4	1.6	147	124	15	258	4	61	48	0
2200	30	<5	8	.3	.5	1.6	157	124	12	268	5	59	48	0
2300	25	5	11	.3	.5	1.5	160	124	12	263	5	58	49	0
2400	26	<5	10	.3	.6	1.6	166	124	12	270	5	58	50	0

TABLE A9. GROUND LEVEL DATA COLLECTED AT THE WSU TRAILER SITE ON SEPTEMBER 16, 1975

	GAS DATA								MET. DATA					
Time	O_3	NO	NO_2	NMTHC	CO	CH_4	$CFCl_3$	CCl_4	WS	WD	σ_θ	TMP	DP	RAD
hr	ppb	ppb	ppb	ppmC	ppm	ppm	ppt	ppt	mph	deg	deg	°F	°F	mLy
0100	18	<5	14	.2	.5	1.6	176	124	13	264	5	57	50	0
0200	24	<5	9	.2	.4	1.6	154	124	13	260	5	57	50	0
0300	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0400	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0500	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0600	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0700	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0800	11	6	18	.3	.6	1.6	154	116	13	263	6	56	50	87
0900	19	5	12	.2	.6	1.5	166	124	13	260	6	58	51	239
1000	16	9	18	.2	.6	1.5	167	124	13	257	7	60	51	510
1100	28	5	8	.3	.5	1.5	174	124	17	265	9	63	51	1051
1200	31	8	14	.4	.6	1.5	183	124	15	270	8	67	51	1210
1300	45	5	13	.3	.6	1.6	189	124	15	275	7	72	52	1276
1400	59	<5	17	.4	.8	1.5	242	124	13	270	10	76	52	1253
1500	74	<5	20	.3	.9	1.6	257	124	13	269	8	80	52	1118
1600	78	<5	16	.3	.8	1.5	211	124	13	270	6	82	51	887
1700	66	<5	22	.3	.9	1.6	223	124	15	272	7	82	52	597
1800	51	<5	25	.3	.9	1.6	217	124	15	283	6	77	52	327
1900	38	<5	33	.4	.7	1.5	211	124	17	276	5	73	51	78
2000	26	<5	25	.3	.6	1.5	177	124	17	279	7	68	51	0
2100	19	<5	22	.3	.6	1.5	164	124	17	273	6	64	51	0
2200	16	<5	21	.3	.6	1.5	155	124	15	278	7	61	51	0
2300	14	<5	19	.2	.6	1.6	158	124	15	273	7	59	51	0
2400	13	<5	18	.3	.5	1.6	158	124	13	268	8	58	51	0

TABLE A10. GROUND LEVEL DATA COLLECTED AT THE WSU TRAILER SITE ON SEPTEMBER 17, 1975

	GAS	DATA							MET.	DATA				
Time hr	O_3 ppb	NO ppb	NO_2 ppb	NMTHC ppmC	CO ppm	CH_4 ppm	$CFCl_3$ ppt	CCl_4 ppt	WS mph	WD deg	σ_θ deg	TMP °F	DP °F	RAD mLy
0100	14	<5	19	.3	.5	1.6	158	116	20	283	6	57	50	0
0200	20	<5	12	.2	.3	1.6	146	124	20	270	5	56	50	0
0300	19	<5	10	.2	.4	1.5	140	124	18	274	6	56	50	0
0400	--	--	--	--	--	--	140	124	--	--	7	56	50	0
0500	18	<5	10	--	--	--	140	124	15	263	6	55	49	0
0600	19	<5	8	--	--	--	140	124	17	262	6	53	48	0
0700	18	<5	10	--	--	--	149	124	13	264	7	54	49	0
0800	14	6	15	--	--	--	158	124	13	274	7	54	49	55
0900	--	--	--	.2	.4	1.5	--	--	--	--	6	57	50	425
1000	13	8	13	--	--	--	--	--	15	271	6	58	51	533
1100	16	14	27	.5	.6	1.6	264	124	17	259	8	66	52	986
1200	28	15	42	.4	1.0	1.7	316	124	20	269	7	70	51	1248
1300	31	12	50	.4	1.3	1.6	332	127	18	265	6	70	51	574
1400	41	9	42	.7	1.0	1.5	264	124	17	270	7	71	51	725
1500	13	7	29	.5	.7	1.6	205	124	13	266	9	77	52	890
1600	42	6	26	.4	.6	1.5	183	124	18	268	5	76	51	541
1700	35	7	29	.3	.6	1.5	167	124	17	269	7	77	51	443
1800	28	4	25	.3	.6	1.5	164	124	17	266	6	75	49	222
1900	18	<5	31	.2	.5	1.6	180	124	13	266	6	72	49	53
2000	13	<5	30	.2	.6	1.6	186	124	12	271	7	68	49	0
2100	6	<5	32	.2	.6	1.6	177	124	13	288	7	64	50	0
2200	9	<5	24	.2	.5	1.5	158	124	13	290	7	60	51	0
2300	13	<5	18	.1	.5	1.5	152	124	15	282	7	58	51	0
2400	17	<5	12	.2	.4	1.4	143	124	22	283	5	57	51	0

TABLE A11. GROUND LEVEL DATA COLLECTED AT THE WSU TRAILER SITE ON SEPTEMBER 18, 1975

	GAS DATA								MET. DATA					
Time	O_3	NO	NO_2	NMTHC	CO	CH_4	$CFCl_3$	CCl_4	WS	WD	σ_θ	TMP	DP	RAD
hr	ppb	ppb	ppb	ppmC	ppm	ppm	ppt	ppt	mph	deg	deg	°F	°F	mLy
0100	20	<5	9	.2	.3	1.4	130	124	20	277	6	56	51	0
0200	16	6	17	.1	.3	1.6	130	124	22	271	6	56	51	0
0300	17	<5	16	.3	.4	1.5	130	124	20	259	6	57	51	0
0400	24	<5	11	.2	.3	1.5	130	133	22	259	6	57	51	0
0500	20	<5	11	.1	.3	1.6	127	124	17	261	7	57	50	0
0600	14	<5	9	.1	.4	1.5	133	124	17	255	7	57	50	0
0700	9	5	12	.1	.5	1.4	152	124	15	256	7	56	49	0
0800	13	6	20	.3	.4	1.5	143	124	17	255	7	57	50	63
0900	25	5	14	.3	.4	1.5	140	124	22	249	6	58	50	179
1000	23	5	12	.2	.4	1.5	152	124	20	249	8	60	50	702
1100	30	6	10	.3	.6	1.5	158	133	18	266	9	63	50	1022
1200	33	8	19	.2	.5	1.6	164	133	22	257	7	64	51	1168
1300	12	5	16	.3	.5	1.4	161	133	20	256	8	68	51	1250
1400	42	6	13	.2	.5	1.5	152	124	20	259	7	70	51	1221
1500	47	<5	14	.3	.6	1.4	152	124	18	260	7	73	51	1100
1600	43	5	15	.2	.6	1.5	150	124	20	257	6	74	51	861
1700	40	7	17	.2	.5	1.5	149	124	15	266	9	72	50	563
1800	32	5	19	.2	.5	1.5	146	124	18	264	7	71	50	298
1900	26	<5	19	.3	.5	1.4	149	124	18	270	7	66	50	63
2000	15	<5	19	.2	.4	1.4	152	124	20	276	6	61	50	0
2100	--	--	--	--	--	--	143	116	--	--	6	59	49	0
2200	20	<5	11	--	--	--	143	124	22	272	5	57	49	0
2300	19	<5	9	.2	.3	1.5	143	124	18	263	5	57	49	0
2400	20	<5	6	.2	.2	1.4	136	124	18	262	5	56	49	0

TABLE A12. GROUND LEVEL DATA COLLECTED AT THE WSU TRAILER SITE ON SEPTEMBER 19, 1975

	GAS DATA								MET. DATA					
Time	O_3	NO	NO_2	NMTHC	CO	CH_4	$CFCl_3$	CCl_4	WS	WD	σ_θ	TMP	DP	RAD
hr	ppb	ppb	ppb	ppmC	ppm	ppm	ppt	ppt	mph	deg	deg	°F	°F	mLy
0100	22	<5	6	.2	.2	1.4	136	124	18	266	5	57	49	0
0200	--	--	--	.1	.4	1.5	127	116	--	--	--	--	--	--
0300	--	--	--	.1	.3	1.5	--	--	--	--	--	--	--	--
0400	--	--	--	.2	.3	1.4	--	--	--	--	--	--	--	--
0500	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0600	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0700	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0800	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0900	--	--	--	.2	.2	1.5	130	116	--	--	--	--	--	--
1000	30	<5	10	.2	.3	1.4	130	124	17	258	8	63	49	872
1100	39	6	8	.2	.2	1.5	136	124	18	263	10	65	49	1055
1200	41	<5	8	.2	.2	1.5	136	124	17	254	8	68	48	1193
1300	34	<5	8	<.1	.2	1.5	130	133	15	251	9	69	49	1255
1400	44	<5	6	<.1	.2	1.6	133	124	18	257	8	72	48	1225
1500	46	5	11	<.1	.2	1.6	140	124	18	263	9	74	49	1093
1600	47	<5	12	<.1	.2	1.6	136	133	18	254	7	72	48	845
1700	35	5	11	<.1	.2	1.6	133	133	18	253	7	71	47	548
1800	34	<5	17	<.1	.2	1.6	140	133	17	259	7	70	48	301
1900	26	<5	18	<.1	.2	1.6	146	133	15	262	5	66	47	43
2000	22	<5	20	<.1	.2	1.6	149	124	13	249	5	61	48	0
2100	23	<5	17	<.1	.2	1.6	146	124	12	259	5	60	48	0
2200	20	5	19	<.1	.2	1.6	152	124	12	256	5	58	49	0
2300	11	5	29	.1	.3	1.7	171	133	12	256	6	59	49	0
2400	19	<5	17	.1	.4	1.6	174	133	12	271	5	57	48	0

TABLE A13. GROUND LEVEL DATA COLLECTED AT THE WSU TRAILER SITE ON SEPTEMBER 20, 1975

	GAS DATA								MET. DATA					
Time	O_3	NO	NO_2	NMTHC	CO	CH_4	$CFCl_3$	CCl_4	WS	WD	σ_θ	TMP	DP	RAD
hr	ppb	ppb	ppb	ppmC	ppm	ppm	ppt	ppt	mph	deg	deg	°F	°F	mLy
0100	8	<5	32	.2	.4	1.6	180	133	12	276	6	57	49	0
0200	18	<5	15	.1	.3	1.6	155	133	12	283	6	56	49	0
0300	23	<5	12	.1	.2	1.6	146	133	13	284	6	56	49	0
0400	19	<5	14	.1	.2	1.7	152	133	12	275	6	56	49	0
0500	15	<5	19	.1	.2	1.7	158	133	12	279	6	56	49	0
0600	5	<5	30	.1	.2	1.8	171	133	13	281	5	56	49	0
0700	6	6	30	.1	.2	1.8	174	133	13	271	5	56	49	0
0800	13	7	25	.1	.2	1.7	183	133	13	272	7	58	50	177
0900	19	8	22	.1	.3	1.7	198	133	13	270	8	61	51	519
1000	20	10	25	.1	.4	1.7	208	124	15	276	7	65	51	807
1100	29	9	21	.1	.4	1.7	233	124	15	272	8	68	50	1048
1200	37	7	21	.1	.4	1.7	248	133	13	272	10	72	50	1191
1300	43	6	22	.1	.5	1.7	242	141	13	274	8	75	51	1257
1400	51	7	24	.1	.6	1.7	257	141	15	280	9	78	52	1330
1500	56	6	25	.1	.6	1.7	249	133	15	282	7	79	52	1105
1600	59	5	30	.1	.6	1.7	231	133	13	278	7	81	52	592
1700	71	5	26	.1	.5	1.7	216	133	15	280	7	81	51	587
1800	56	5	33	.1	.5	1.7	210	133	17	280	6	78	52	230
1900	36	<5	25	.1	.3	1.6	186	124	18	292	6	73	51	34
2000	22	<5	27	.2	.5	1.6	183	133	18	273	6	69	50	0
2100	16	<5	28	.2	.3	1.6	165	133	18	285	7	66	51	0
2200	14	<5	26	.2	.3	1.6	165	133	18	277	6	64	51	0
2300	13	<5	27	.1	.3	1.6	168	133	15	283	8	65	51	0
2400	12	5	24	.2	.4	1.6	183	124	17	282	8	63	50	0

TABLE A14. GROUND LEVEL DATA COLLECTED AT THE WSU TRAILER SITE ON SEPTEMBER 21, 1975

	GAS DATA								MET. DATA					
Time hr	O_3 ppb	NO ppb	NO_2 ppb	NMTHC ppmC	CO ppm	CH_4 ppm	$CFCl_3$ ppt	CCl_4 ppt	WS mph	WD deg	σ_θ deg	TMP °F	DP °F	RAD mLy
0100	7	<5	32	.1	.3	1.7	198	133	17	281	6	60	50	0
0200	8	<5	28	.1	.2	1.7	174	133	20	276	6	58	50	0
0300	13	<5	19	.1	.2	1.7	162	133	17	273	6	56	50	0
0400	18	<5	14	.1	.2	1.6	144	133	20	273	6	55	50	0
0500	12	<5	19	.2	.4	1.6	141	133	17	268	6	55	50	0
0600	20	<5	11	.2	.2	1.6	141	133	17	272	6	55	50	0
0700	23	<5	7	.1	.2	1.6	141	133	17	276	6	55	50	0
0800	21	<5	13	.1	.2	1.7	144	133	17	271	6	56	50	0
0900	26	<5	10	.1	.3	1.6	147	133	17	266	7	58	50	141
1000	26	6	14	.1	.3	1.6	177	133	18	268	7	60	50	496
1100	28	7	21	.2	.4	1.6	216	124	18	289	6	63	51	780
1200	36	7	20	.2	.6	1.6	222	133	18	285	7	68	51	896
1300	45	5	16	.2	.5	1.6	231	133	13	274	7	72	51	1006
1400	44	7	25	.2	.5	1.5	255	124	13	280	11	77	52	1265
1500	45	7	32	.2	.4	1.5	285	133	20	274	7	74	51	1248
1600	54	5	26	.2	.4	1.5	237	133	17	274	7	79	52	710
1700	58	5	29	.2	.4	1.5	174	133	14	276	8	78	51	865
1800	43	5	32	--	--	--	210	133	17	279	6	76	51	517
1900	33	<5	30	--	--	--	189	133	19	279	7	69	51	287
2000	14	5	34	--	--	--	174	133	17	263	6	64	50	43
2100	17	6	22	--	--	--	183	133	15	272	7	61	52	0
2200	2	5	44	--	--	--	210	133	17	272	7	60	51	0
2300	3	5	40	--	--	--	216	133	17	264	6	59	51	0
2400	4	6	38	--	--	--	192	133	15	274	8	57	51	0

TABLE A15. GROUND LEVEL DATA COLLECTED AT THE WSU TRAILER SITE ON SEPTEMBER 22, 1975

Time	GAS DATA								MET. DATA					
Time hr	O_3 ppb	NO ppb	NO_2 ppb	NMTHC ppmC	CO ppm	CH_4 ppm	$CFCl_3$ ppt	CCl_4 ppt	WS mph	WD deg	σ_θ deg	TMP °F	DP °F	RAD mLy
0100	14	5	27	--	--	--	174	133	15	276	6	57	51	0
0200	20	<5	17	--	--	--	165	124	14	277	6	56	51	0
0300	21	<5	14	--	--	--	156	133	17	281	6	56	51	0
0400	23	<5	12	--	--	--	150	133	17	278	5	56	51	0
0500	27	<5	11	--	--	--	144	124	17	274	5	56	51	0
0600	28	<5	10	--	--	--	147	133	15	273	6	55	51	0
0700	19	5	20	--	--	--	162	133	15	267	6	55	51	0
0800	16	6	28	--	--	--	204	133	17	267	5	57	51	186
0900	18	13	36	--	--	--	246	133	17	274	6	60	52	498
1000	24	12	34	--	--	--	282	133	15	273	7	63	52	785
1100														
1200														
1300														
1400														
1500														
1600														
1700														
1800														
1900														
2000														
2100														
2200														
2300														
2400														

TABLE A16. UPPER LEVEL WIND DIRECTION AND SPEED RECORDED ON SEPTEMBER 9, 1975

Height(ft)	Wind Direction & Speed*			
	WSU Trailer (1130)	Antioch #1 (1240)	Antioch #2 (1320)	Pittsburgh (1410)
350	279/21	283/11	303/18	291/17
710	281/21	282/05	301/13	288/16
1030	257/19	266/06	275/07	258/19
1360	223/19	259/10	282/04	244/23
1680	227/16	250/11	246/04	238/18
2010	241/09	247/13	250/08	256/10
2320	284/07	263/11	245/12	285/09
2630	290/06	258/09	245/12	279/08
2940	339/08	278/11	261/11	283/10
3250	335/12	305/10	263/08	281/05
3540	337/16	318/13	295/08	036/04
3840	329/19	326/15	313/10	336/06
4130	320/19	325/17	323/13	326/07
4430	317/19	324/18	330/14	309/10
4720	318/20	321/20	326/15	310/14
5020	313/21	312/22	314/18	312/17
5320	319/21	307/22	303/19	312/19
5610	323/19	298/18	297/17	303/19
5900	325/18	285/14	291/15	297/18

*Wind direction in degrees and speed in miles per hour

TABLE A17. UPPER LEVEL WIND DIRECTION AND SPEED RECORDED ON SEPTEMBER 10, 1975

Height(ft)	Wind Direction & Speed*					
	Emmaton (1015)	Antioch (1100)	Brentwood (1135)	Pittsburgh (1220)	Port Chicago (1255)	WSU Trailer (1325)
350	272/32	295/25	149/02	247/20	297/10	263/18
710	270/27	266/25	275/03	244/19	280/06	259/16
1030	259/19	256/18	266/03	232/18	253/05	270/17
1360	275/12	257/11	262/09	233/14	227/07	268/20
1680	295/05	267/05	246/11	232/08	207/09	263/14
2010	347/03	161/04	233/05	205/05	200/08	257/05
2320	085/08	107/08	160/06	170/05	159/07	195/02
2630	081/09	099/08	124/07	138/06	143/07	049/02
2940	079/07	094/07	130/05	152/06	126/06	077/04
3250	058/07	085/07	140/04	092/07	134/06	142/07
3540	076/05	082/06	063/04	093/05	095/04	120/06
3840	035/04	058/04	056/03	089/04	107/02	129/04
4130	011/04	040/03	361/04	061/03	011/02	119/03
4430	342/05	005/03	344/06	025/03	006/03	252/01
4720	340/07	355/05	326/07	345/04	314/04	022/02
5020	303/12	328/07	300/08	305/06	273/06	015/03
5320	293/13	314/09	289/10	286/09	301/07	294/03
5610	291/15	301/11	286/11	268/11	275/08	299/05
5900	285/13	285/13	283/11	263/10	268/09	301/06

*Wind direction in degrees and speed in miles per hour

TABLE A18. UPPER LEVEL WIND DIRECTION AND SPEED RECORDED ON SEPTEMBER 11, 1975

Height(ft)	Wind Direction & Speed*				
	Hood (1525)	Poverty Rd (1620)	Dozier & Hwy 113 (1705)	Collinsville (1745)	Antioch (1900)
350	242/12	257/23	229/16	266/20	281/23
710	242/13	260/25	239/20	256/20	270/26
1030	243/14	257/27	247/23	256/21	267/23
1360	241/15	258/28	249/24	265/23	269/26
1680	248/14	259/23	249/20	262/23	271/26
2010	260/13	259/16	248/14	263/21	270/18
2320	271/11	259/13	239/11	271/17	276/15
2630	290/10	273/12	239/08	277/15	283/13
2940	307/11	275/12	235/06	275/15	282/09
3250	305/11	270/09	255/04	268/14	277/07
3540	332/11	298/08	295/06	272/11	278/06
3840	318/10	302/07	324/08	277/09	304/05
4130	297/08	294/08	328/07	284/05	312/04
4430	285/07	280/09	330/06	319/05	321/03
4720	276/04	280/10	327/04	323/06	327/03
5020	256/06	280/09	298/05	297/07	316/05
5320	259/07	289/08	306/04	282/07	304/06
5610	107/04	285/08	304/02	281/06	286/06
5900	135/02	282/07	CALM	254/06	288/07

*Wind direction in degrees and speed in miles per hour

TABLE A19. UPPER LEVEL WIND DIRECTION AND SPEED RECORDED ON SEPTEMBER 12, 1975

Height(ft)	Wind Direction & Speed *		
	WSU Trailer (1730)	Rockville (1810)	Port Chicago (1930)
350	275/23	270/25	250/09
710	271/35	280/27	236/10
1030	271/38	280/24	234/11
1360	265/21	268/18	245/15
1680	249/16	268/10	258/18
2010	256/13	280/06	259/20
2320	270/09	270/05	258/20
2630	276/07	261/06	251/17
2940	270/06	260/07	235/15
3250	258/05	256/07	234/14
3540	263/05	257/07	241/14
3840	280/06	258/06	249/10
4130	271/06	260/02	253/08
4430	243/06	267/01	265/05
4720	217/04	284/02	276/02
5020	254/03	288/02	331/01
5320	261/03	270/03	216/01
5610	256/03	262/03	185/01
5900	272/03	266/04	159/03

*Wind direction in degrees and speed in miles per hour

TABLE A20. UPPER LEVEL WIND DIRECTION AND SPEED RECORDED ON SEPTEMBER 13, 1975

Hght. (ft)	Wind Direction & Speed*				
	WSU Trailer (1220)	Crockett (1305)	Intersection Hwys 23/12 (1400)	Rutherford (1500)	Sonoma (1640)
177	266/31	267/18	246/16	150/06	253/11
500	265/32	237/07	263/15	153/08	267/08
863	257/31	233/09	280/10	162/06	314/08
1188	259/29	260/11	275/11	189/05	315/11
1500	248/21	243/09	286/12	288/02	270/08
1840	247/18	216/08	290/14	254/02	336/09
2153	203/04	187/06	267/08	275/05	253/07
2500	218/07	198/07	242/10	268/07	232/09
2775	205/07	197/07	212/10	269/08	212/07
3000	203/08	197/09	219/09	261/09	230/08
3382	161/08	189/09	215/08	225/13	205/08
3678	182/08	191/12	208/09	219/13	221/12
4000	161/07	197/12	193/10	208/10	210/10
4270	180/08	203/13	193/11	202/10	209/11
4500	172/09	198/12	195/11	200/10	207/11
5000	199/11	---	205/12	207/11	205/11
5500	199/10	---	193/11	212/15	194/11
6000	---	---	189/12	200/11	188/11

*Wind direction in degrees and speed in miles per hour

TABLE A21. UPPER LEVEL WIND DIRECTION AND SPEED RECORDED ON SEPTEMBER 14, 1975

Height (ft.)	Wind Direction & Speed*	
	WSU Trailer (1440)	Grizzly Island (1610)
177	248/15	263/17
500	254/15	259/19
863	256/13	254/20
1188	268/16	254/22
1500	260/15	265/18
1840	256/14	282/12
2153	284/04	298/05
2500	222/02	317/02
2775	120/04	067/02
3000	131/05	191/02
3382	135/06	214/03
3678	153/07	228/05
4000	167/09	194/05
4270	128/08	196/06
4500	154/08	174/07
5000	172/11	171/12
5500	172/15	167/13
6000	173/18	173/17

*Wind direction in degrees and speed in miles per hour

APPENDIX B

Data from each aircraft flight is summarized in Appendix B. Information on flight paths, traverses of the Exxon plume and vertical spirals is given for each individual flight. When flights were aimed specifically at investigating downwind ozone buildup, ozone concentrations are marked along the route. Where possible, plots of ozone concentrations from the Exxon refinery inland to the delta region have also been provided.

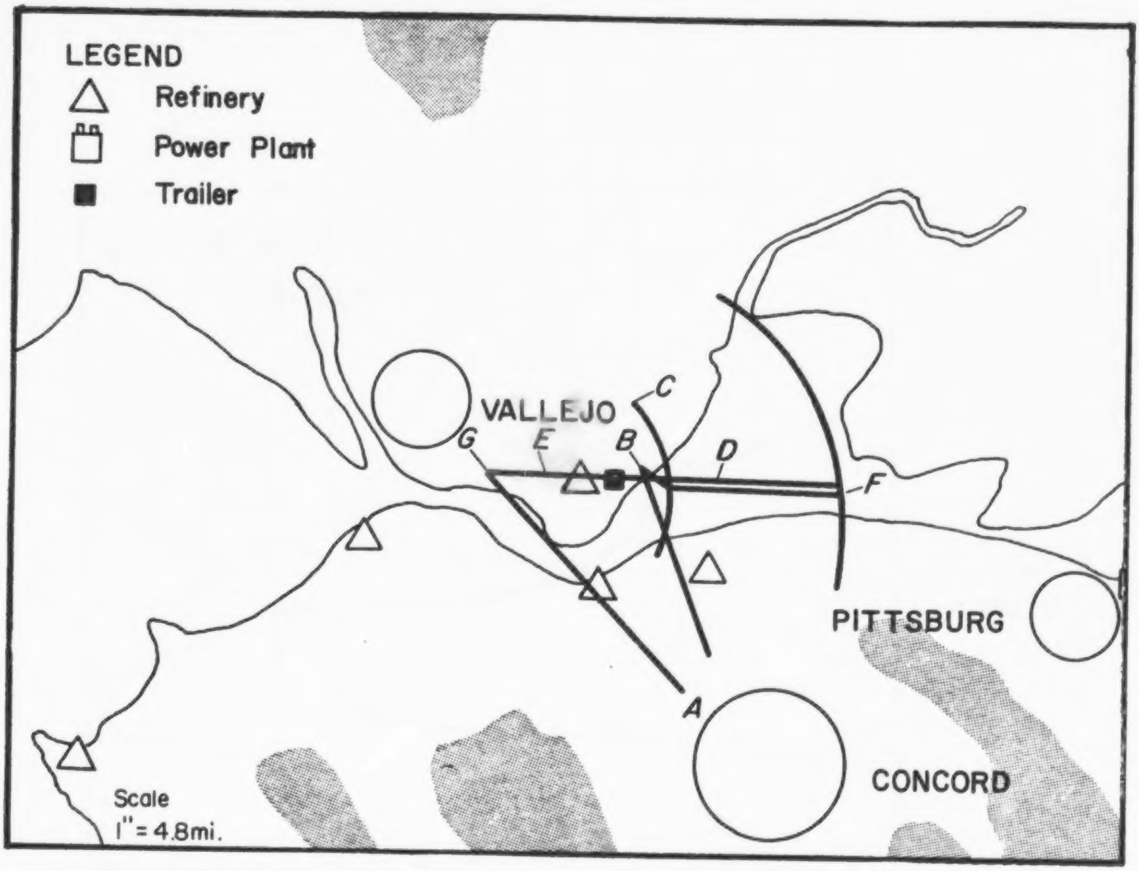

LEGEND
△ Refinery
Power Plant
■ Trailer
VALLEJO
PITTSBURG
CONCORD
A
B
C
D
E
F
G
Scale
1" = 4.8mi.

Figure B1 . Flight path on September 8, 1975.

TIME: 11:10 AM - 12:40 PM

LEG
A- Buchanan field, climb to 1,500 feet
B- Napa 094/11, spiral up to 7,000 feet and down to 500 feet
C- 2½ mile arc of refinery at 1,000 feet
D- End arc
E- Reverse track in line with plume
F- 8 mile arc of refinery
G- 2 mile upwind of refinery

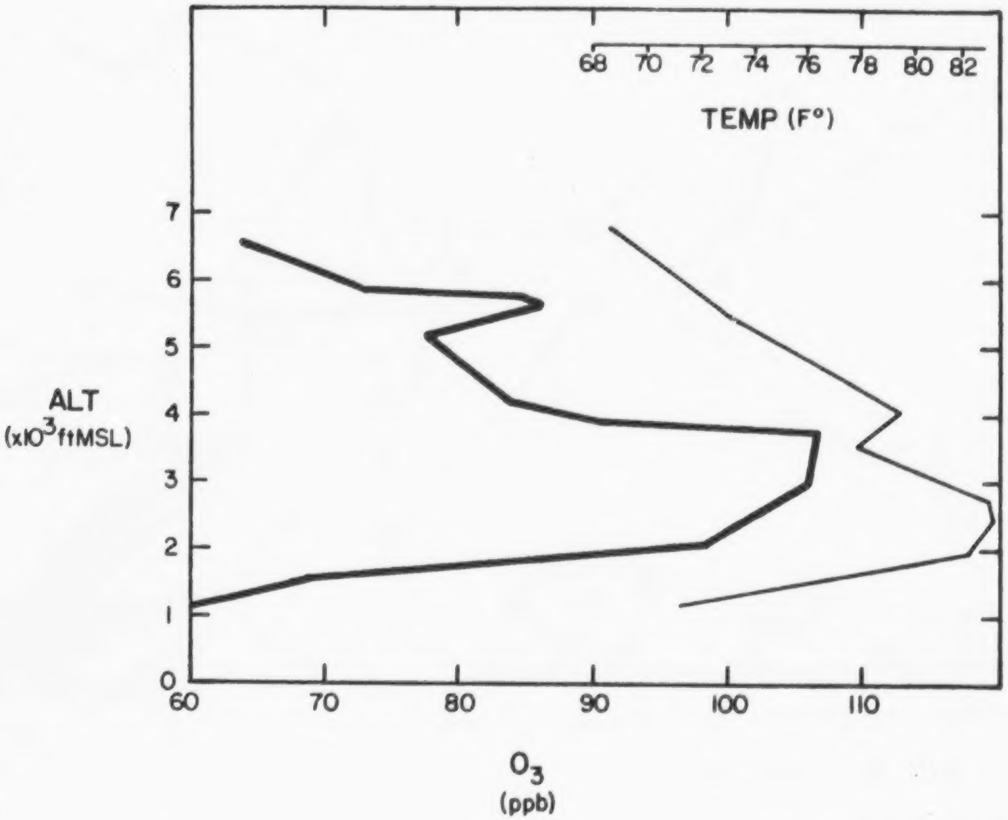


Figure B2. Plot of ozone and temperature data recorded during a vertical spiral over the WSU trailer on September 8, 1975.

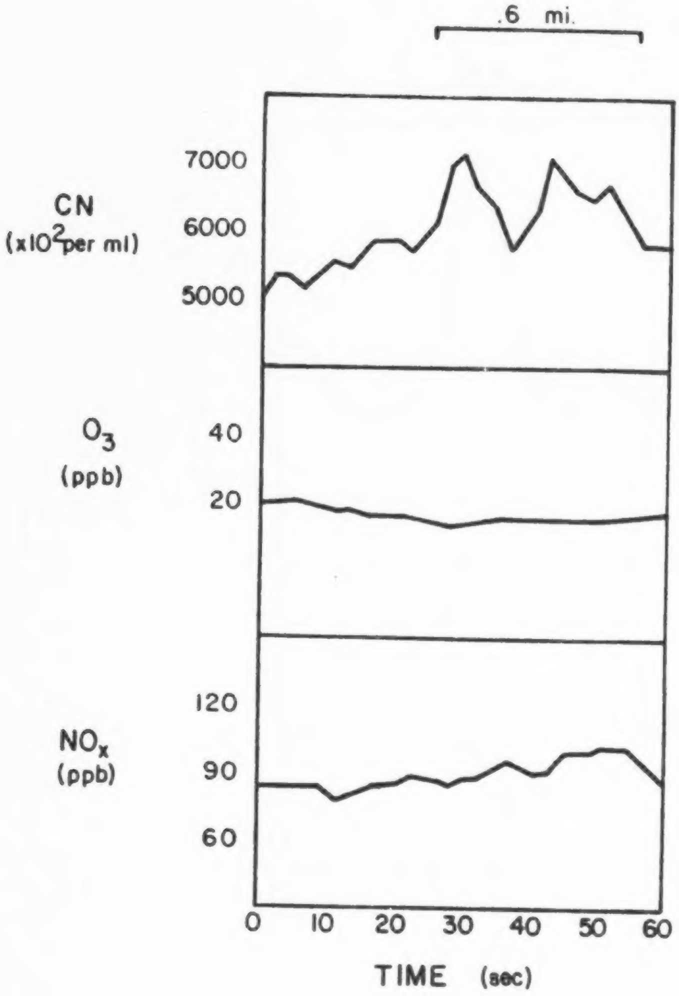


Figure B3. Plot of aircraft data recorded on September 8 during traverse of refinery plume 2 miles downwind at 800 ft. AGL.

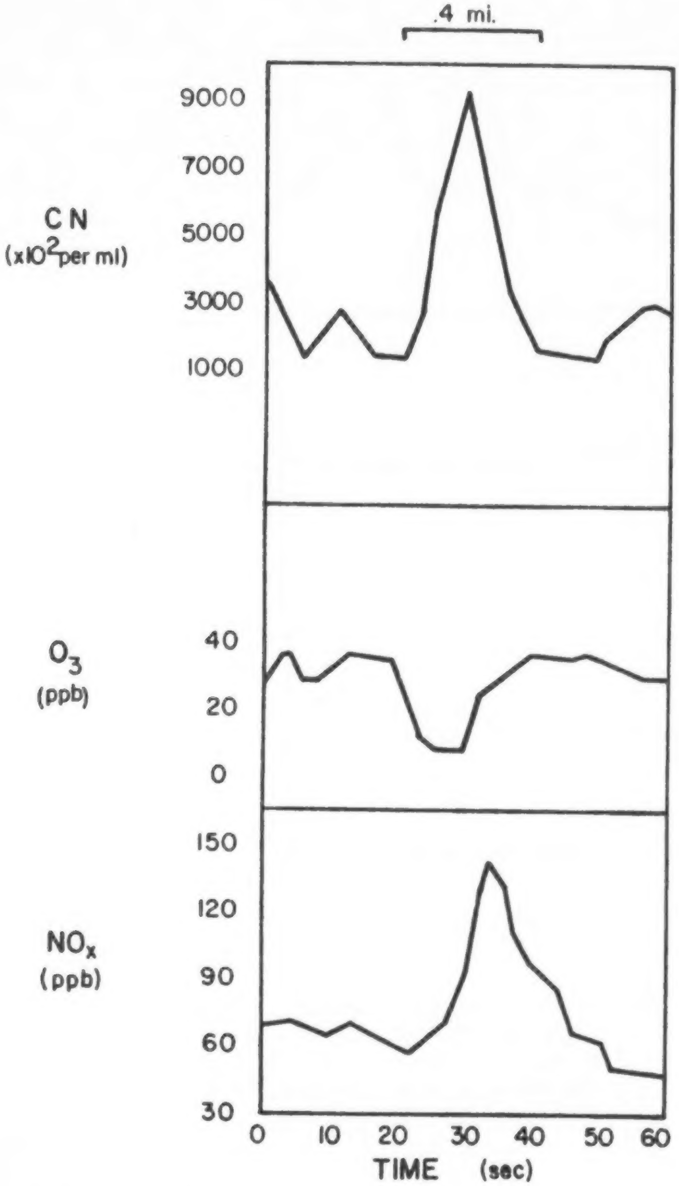


Figure B4. Plot of aircraft data recorded on September 8 during traverse of refinery plume 2 miles downwind at 850 ft. AGL.

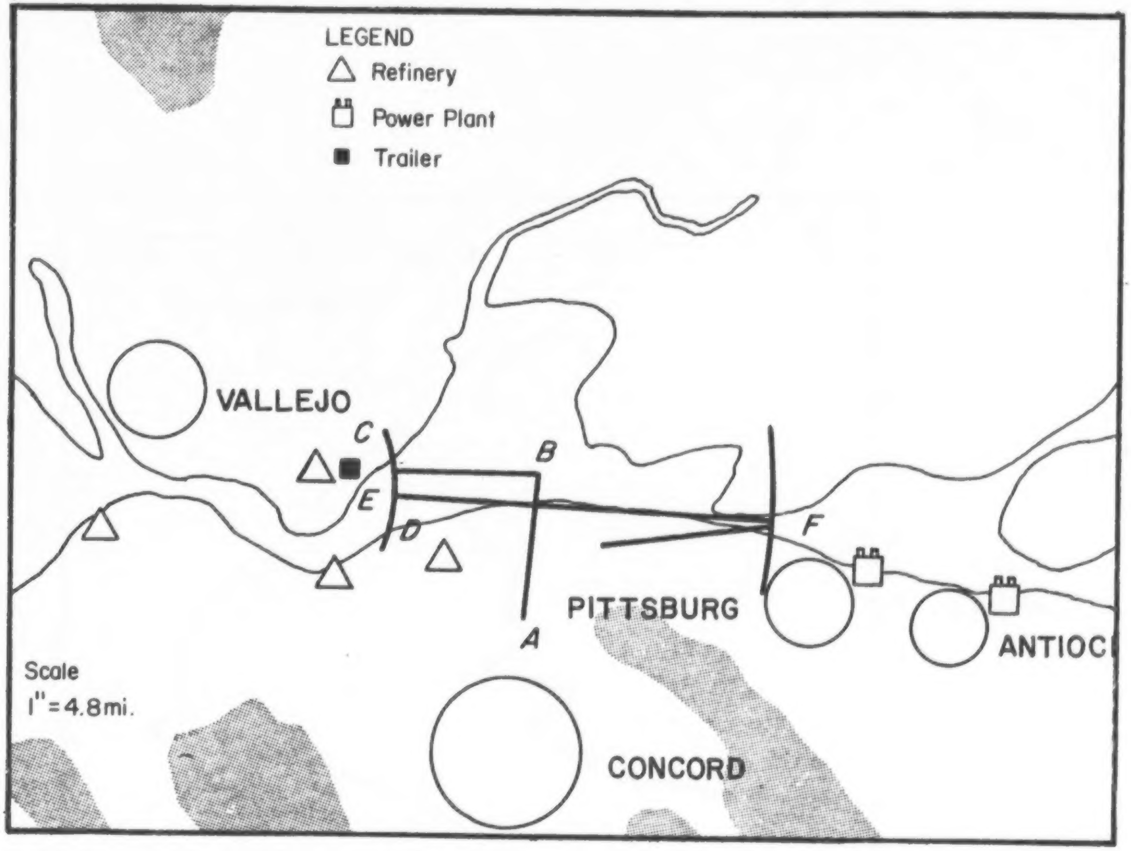

LEGEND
△ Refinery
Power Plant
■ Trailer
VALLEJO
C
B
E
D
F
PITTSBURG
A
ANTIOC
Scale
1"=4.8mi.
CONCORD

Figure B5 . Flight path on September 8, 1975.

TIME: 5:40 PM - 6:45 PM

LEG
- A- Buchanan Field, climb to 1,500 feet
- B- Roe Island
- C- 2½ mile arc of refinery
- D- Napa 102/12, spiral up to 7,000 feet and down to 500 feet
- E- Turn to fly down plume
- F- 14 mile arc of refinery, spiral to 2,000 feet

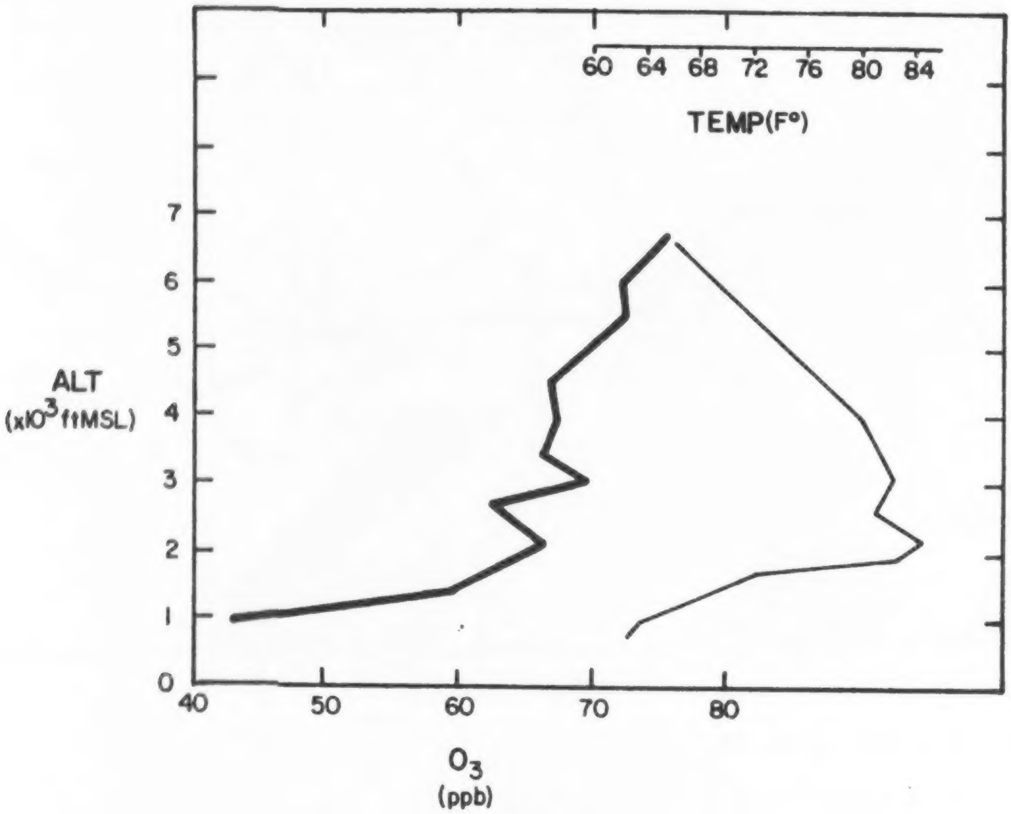


Figure B6. Plot of ozone and temperature data recorded during a vertical spiral over the WSU trailer on September 8, 1975.

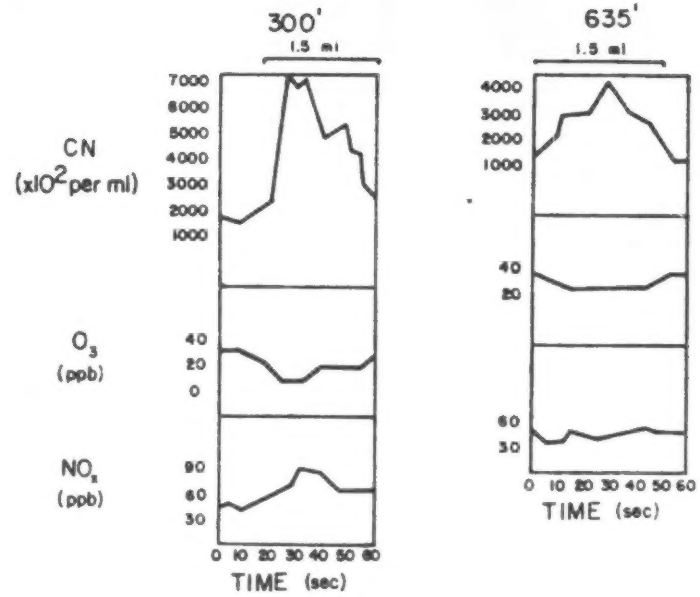


Figure B7. Plot of aircraft data recorded on September 8 during traverses of refinery plume 1 mile downwind.

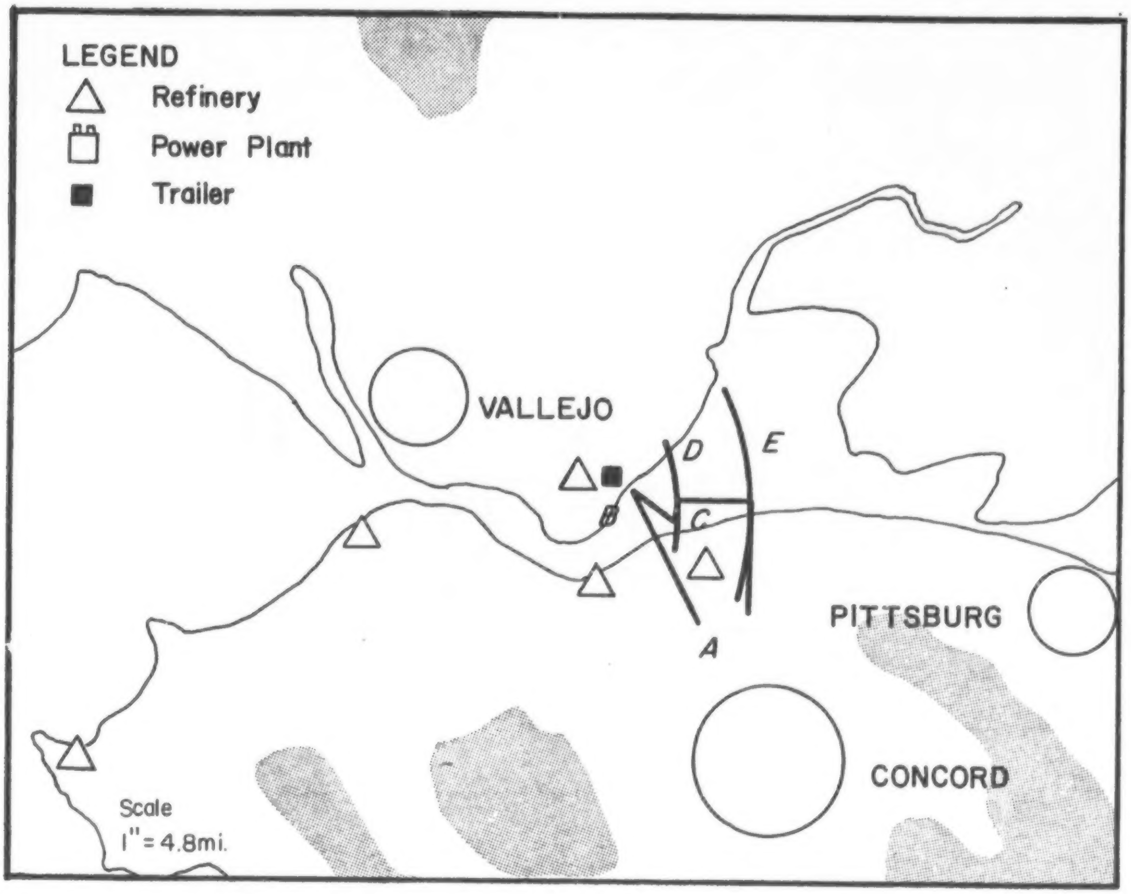

LEGEND
△ Refinery
Power Plant
■ Trailer
VALLEJO
PITTSBURG
CONCORD
A
B
C
D
E
Scale
1" = 4.8mi.

Figure B8 . Flight path on September 9, 1975.

TIME: 9:55 AM - 12:00 PM

LEG
- A- Buchanan Field, climb to 1,500 feet
- B- Spiral up to 6,000 feet
- C- Spiral down to 1,200 feet
- D- 3 mile arcs of refinery at 1,200 feet, 1,000 feet, 750 feet and 500 feet
- E- 5 mile arcs of refinery at 500 feet, 750 feet, 1,000 feet, 1,200 feet, and 2,000 feet

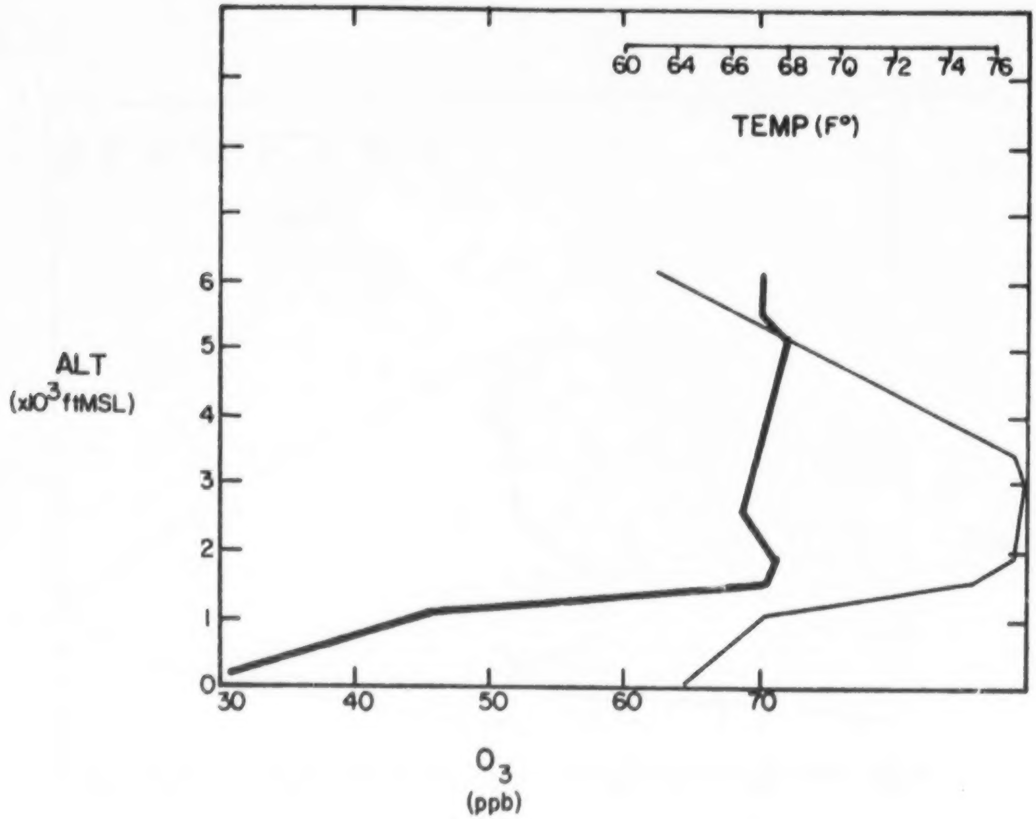


Figure B9. Plot of ozone and temperature data recorded during a vertical spiral over the WSU trailer on September 9, 1975.

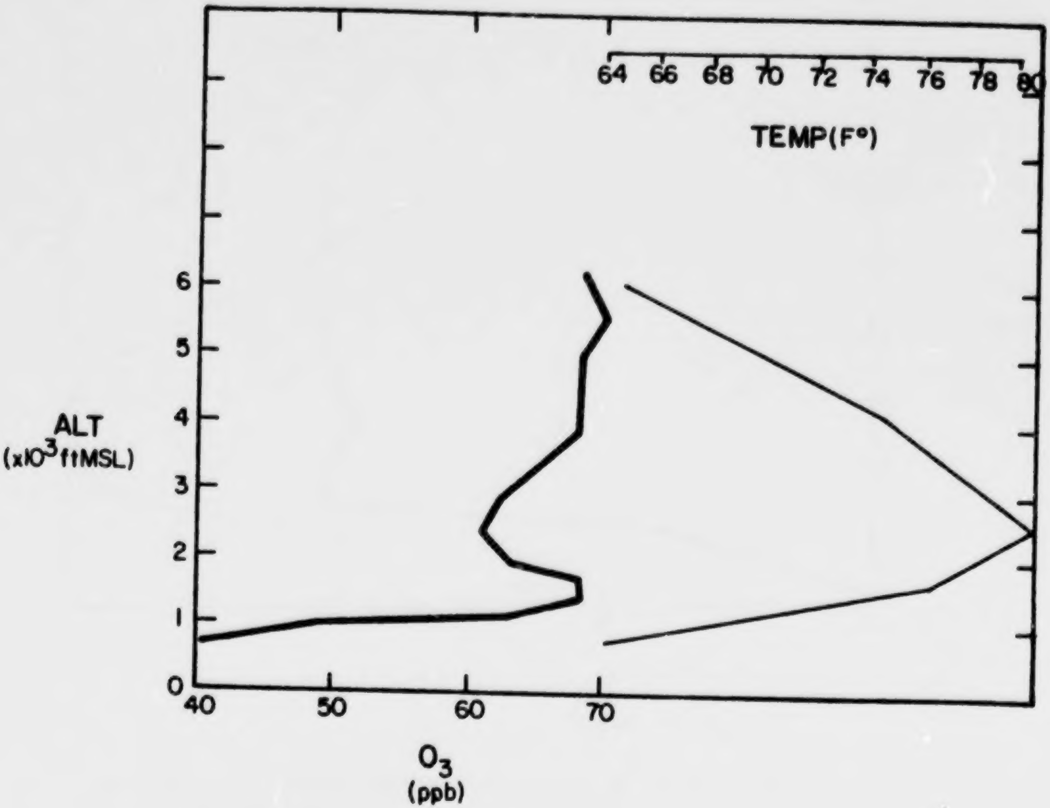


Figure B10. Plot of ozone and temperature data recorded during a vertical spiral 3 miles east of Benicia on September 9, 1975.

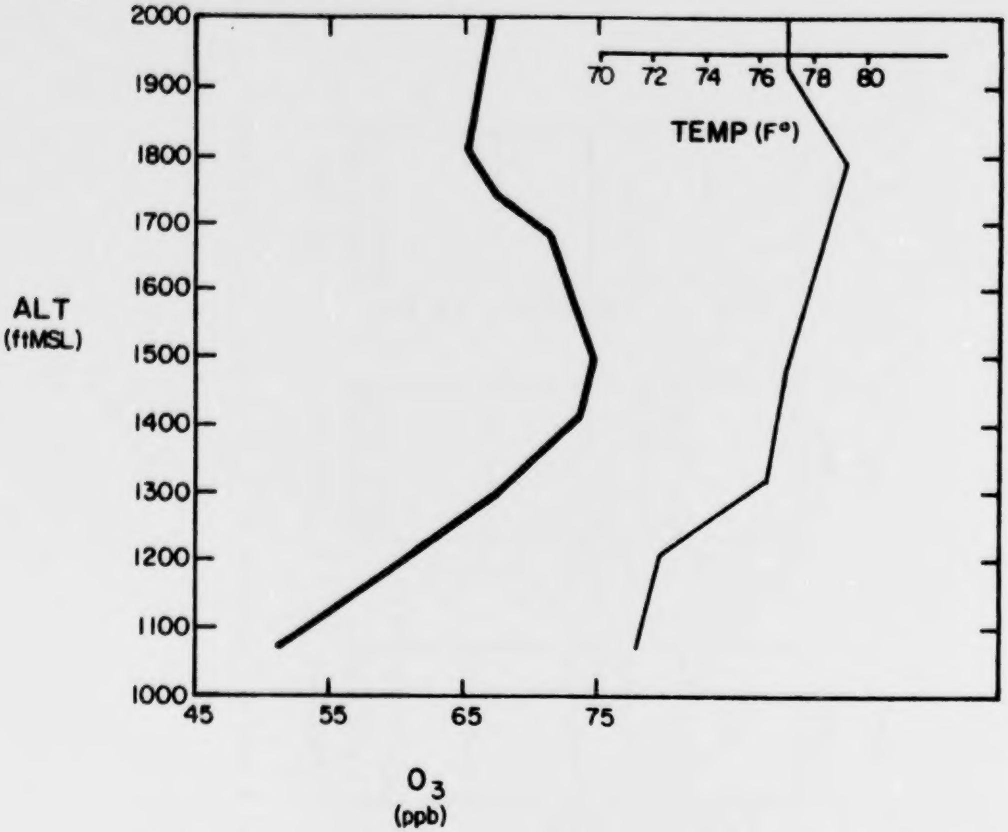


Figure B11. Plot of ozone and temperature data recorded during a vertical spiral 5 miles east of Benicia on September 9, 1975.

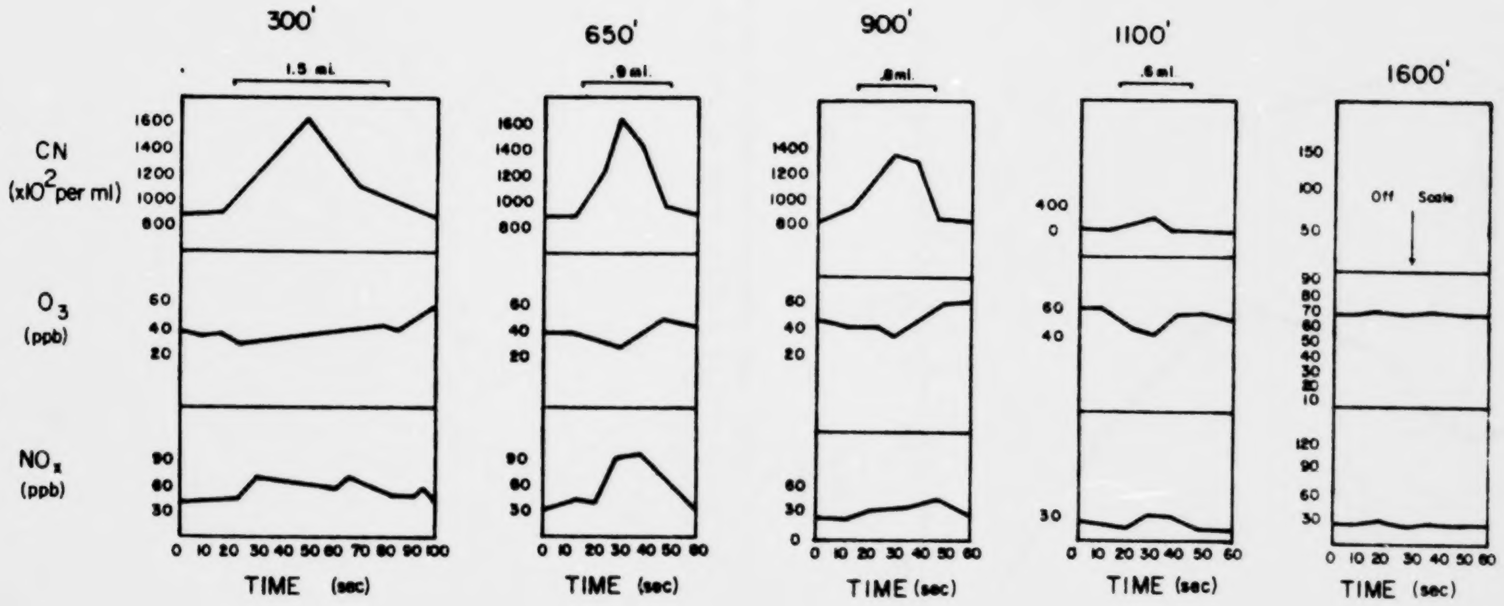


Figure B12. Plot of aircraft data recorded on September 9 during traverses of the refinery plume 3 miles downwind.

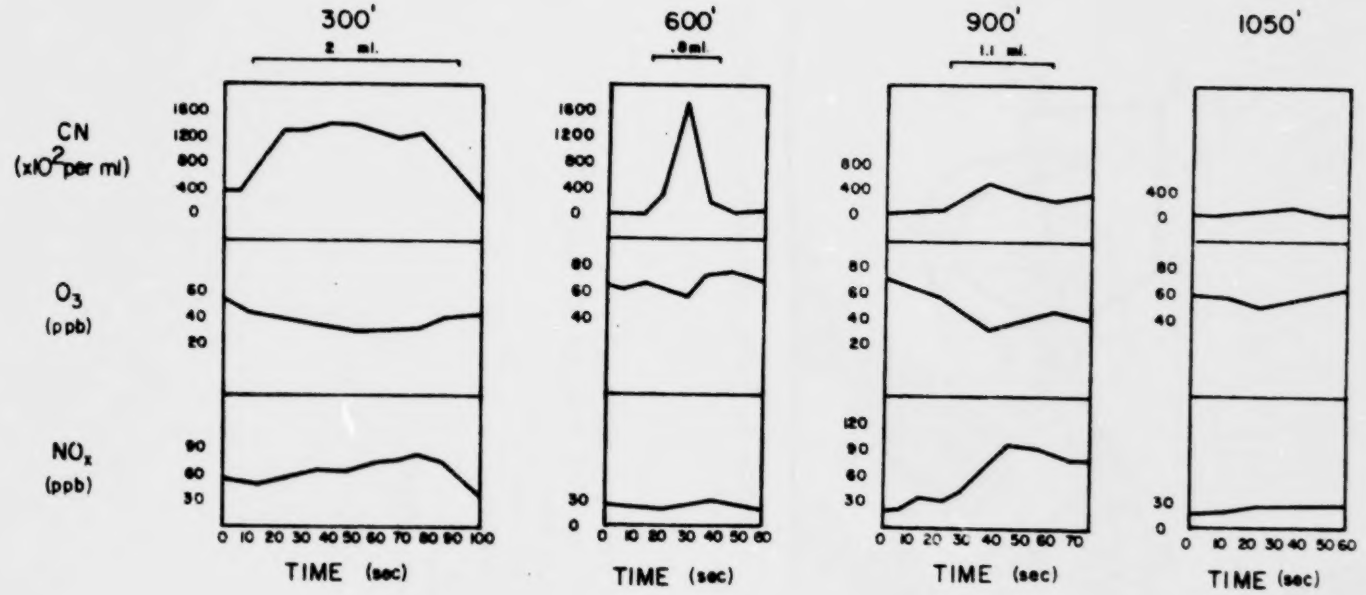


Figure B13. Plot of aircraft data recorded on September 9 during traverses of the refinery plume 5 miles downwind.

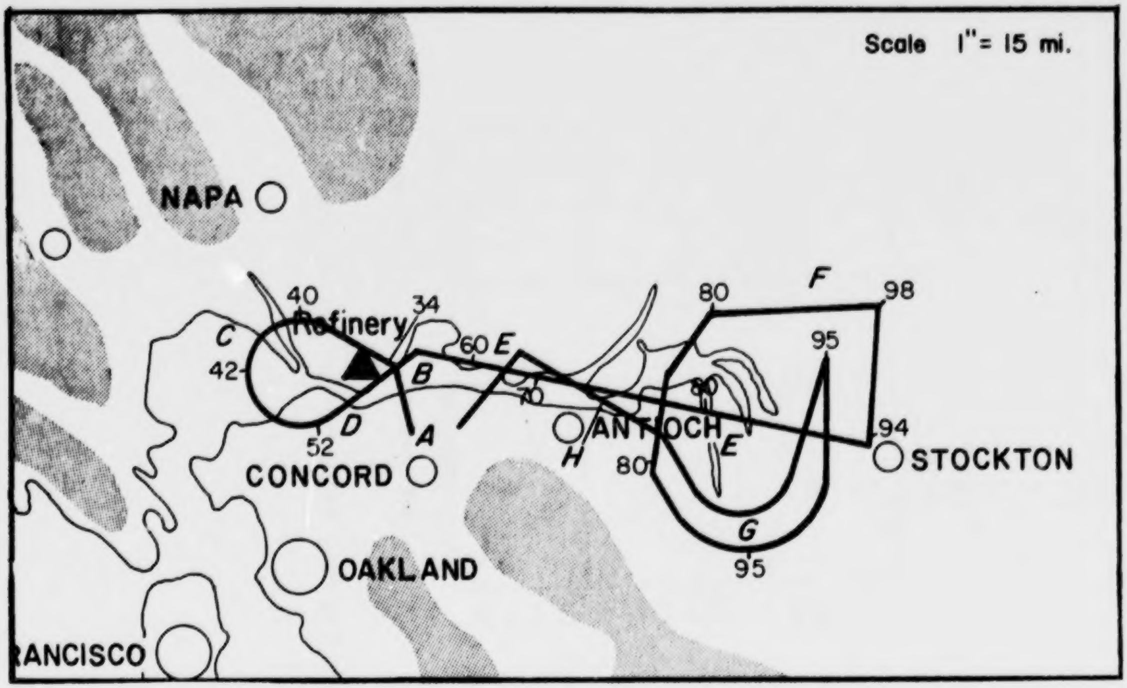

Scale 1"= 15 mi.
NAPA
40
34
Refinery
C
42
60
E
B
70
80
F
98
95
80
D
A
52
CONCORD
ANTIOCH
H
80
E
94
STOCKTON
G
95
OAKLAND
ANCISCO

Figure B14. Flight path on September 9, 1975, with ozone concentrations (ppb) marked along the route.

TIME: 3:05 PM - 5:35 PM

LEG	
A-	Buchanan Field, climb to 1,000 feet
B-	Spiral up to 8,000 feet and down to 500 feet
C-	Upwind loop at 1,200 feet
D-	Rodeo, descend to 800 feet
E-	Follow plume to Stockton
F-	North downwind loop
G-	South downwind loops
H-	Diagonal cross plume track

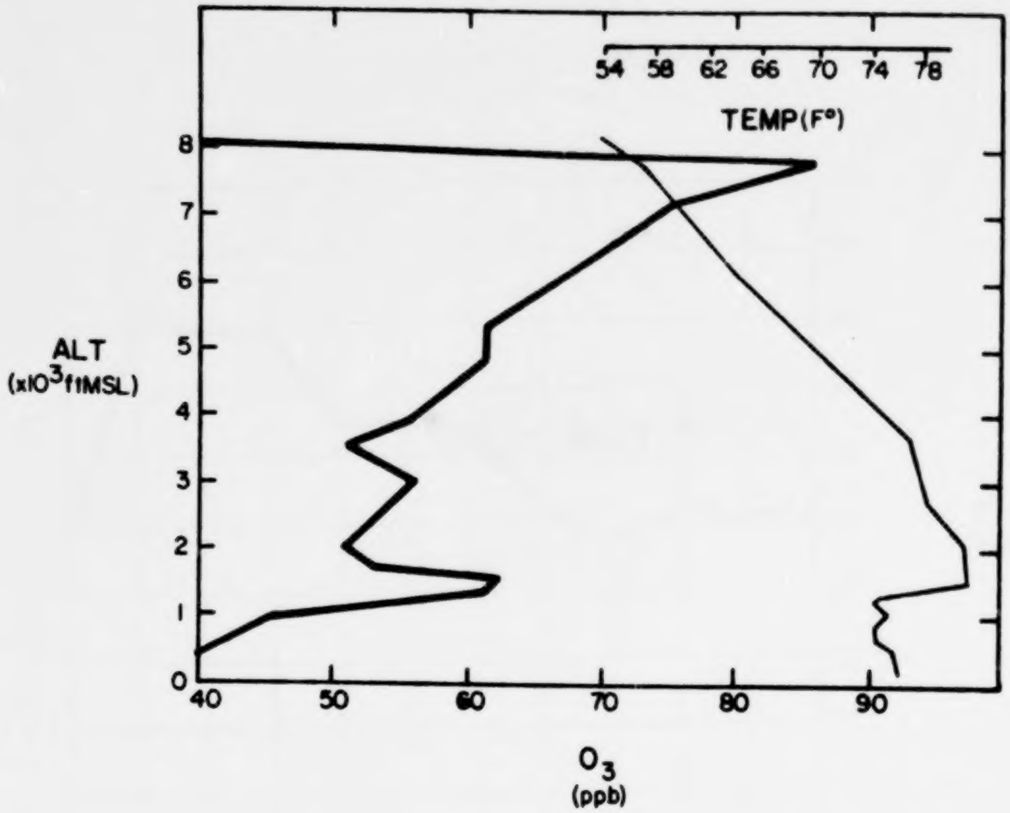


Figure B15. Plot of ozone and temperature data recorded during a vertical spiral over the WSU trailer on September 9, 1975.

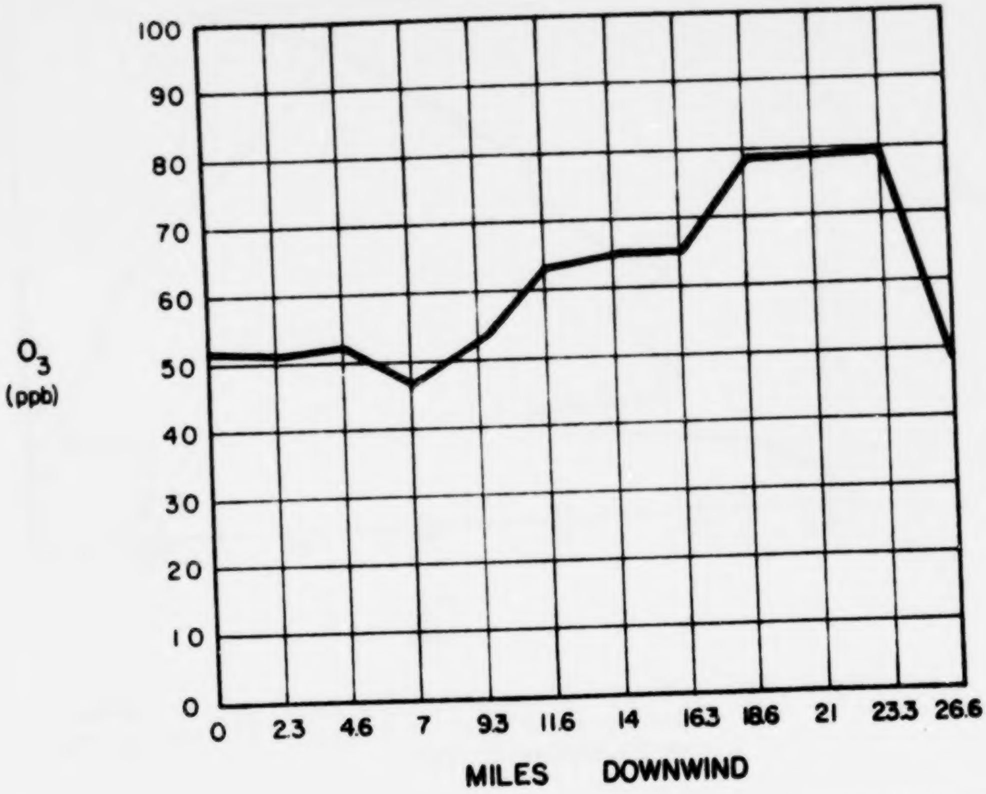


Figure B16. Plot of ozone concentrations versus distance downwind of Exxon refinery on September 9, 1975.

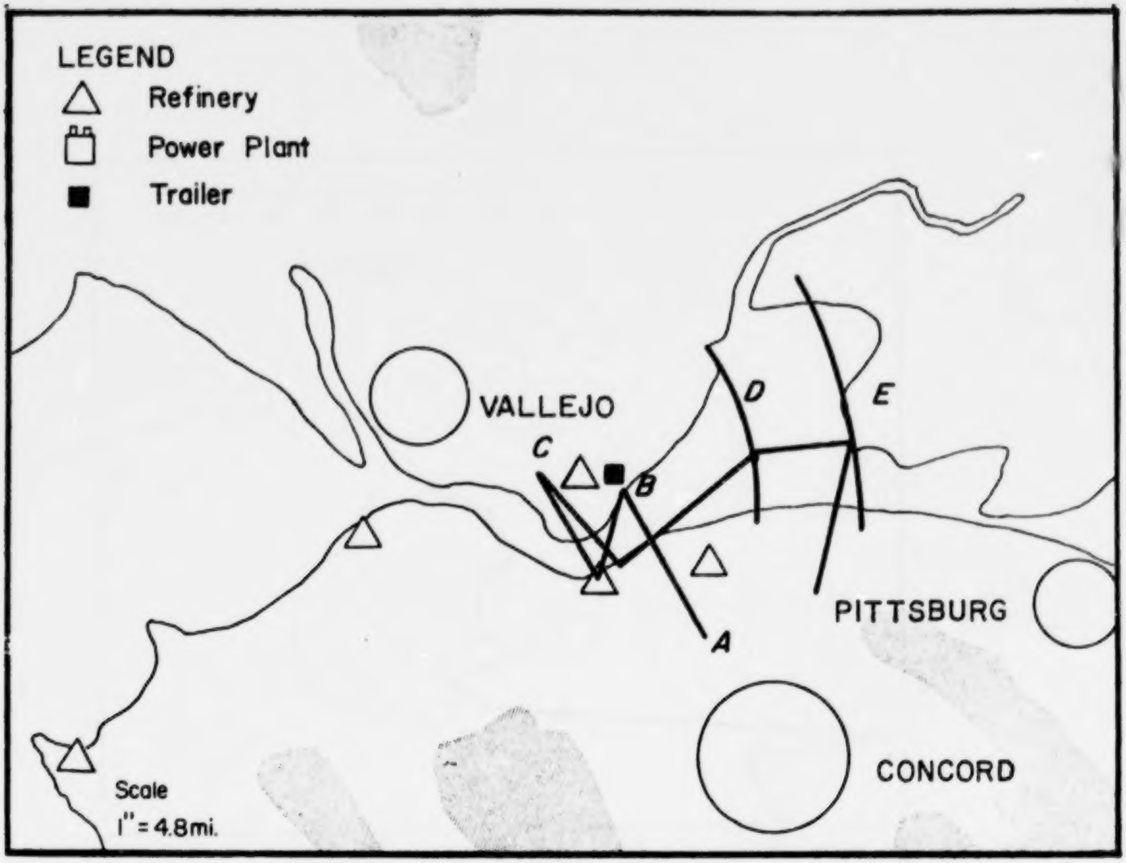

LEGEND
△ Refinery
Power Plant
■ Trailer
VALLEJO
PITTSBURG
CONCORD
A
B
C
D
E
Scale
1" = 4.8 mi.

Figure B17. Flight path on September 10, 1975.

TIME: 10:35 AM - 12:05 PM

LEG
- A- Buchanan Field, climb to 1,000 feet
- B- Napa 094/11, spiral up to 5,000 feet and down to 500 feet
- C- 1 mile west of refinery
- D- 5 mile arcs at 500 feet, 750 feet, 1,000 feet, 1,200 feet, and spiral to 1,500 feet
- E- 8 mile arcs at 500 feet, 750 feet, 1,000 feet, 1,200 feet, and spiral to 1,700 feet

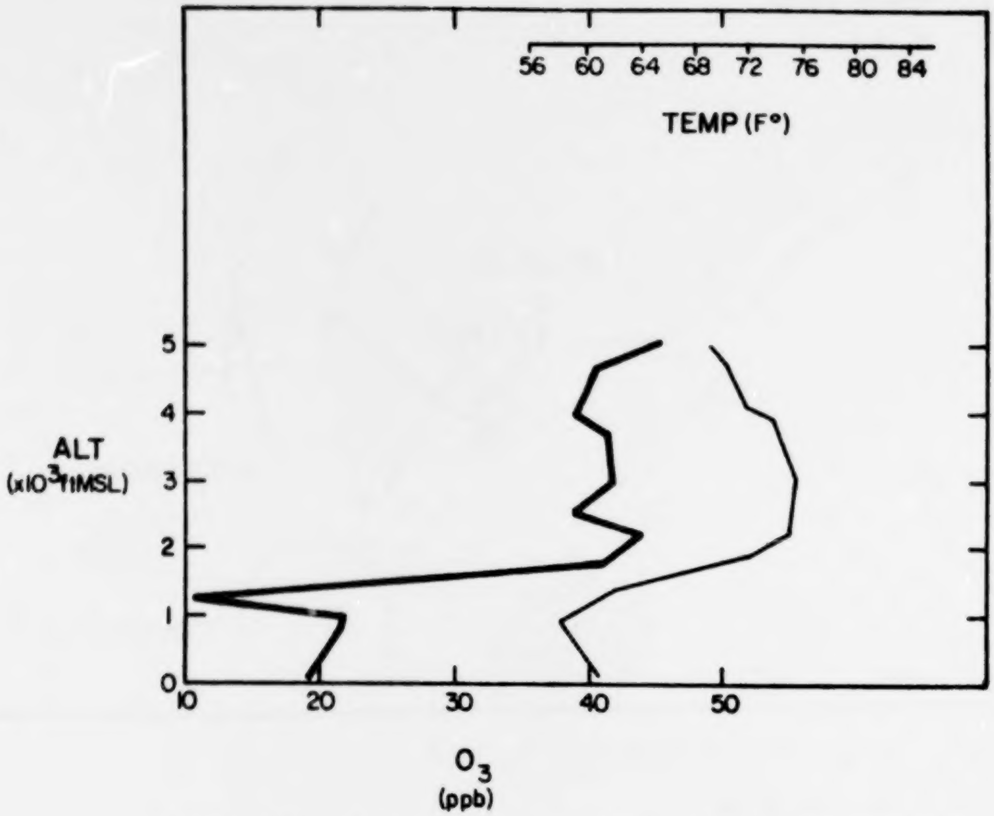


Figure B18. Plot of ozone and temperature data recorded during a vertical spiral over the WSU trailer on September 10, 1975.

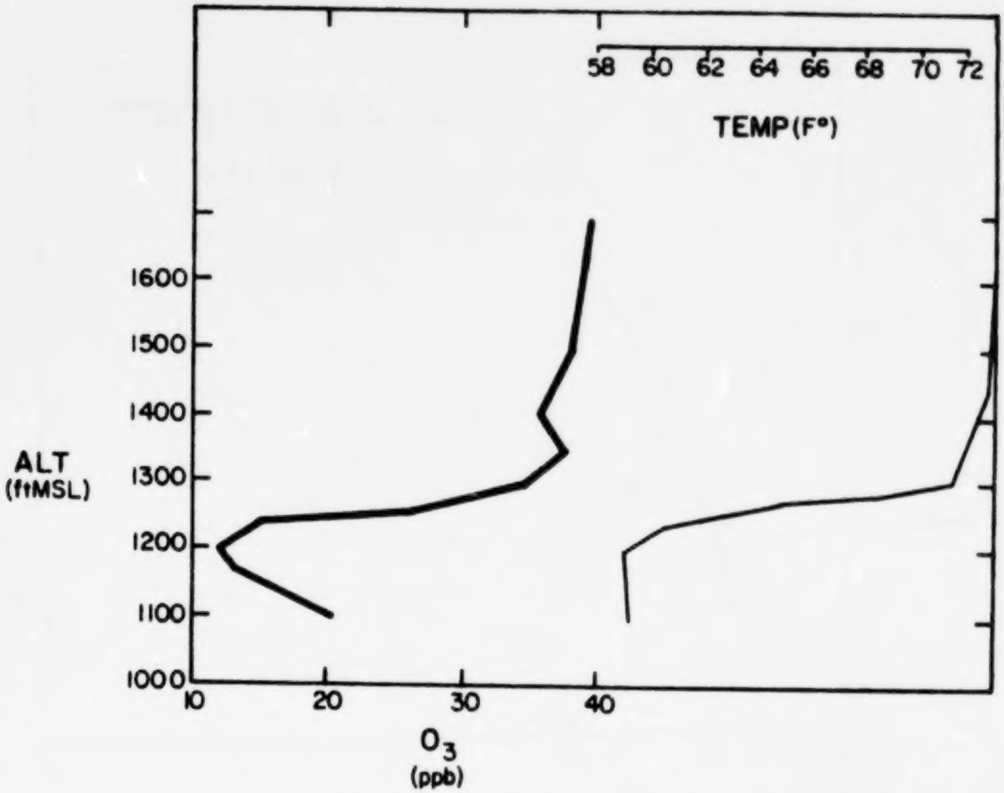


Figure B19. Plot of ozone and temperature data recorded during a vertical spiral 5 miles east of Benicia on September 10, 1975.

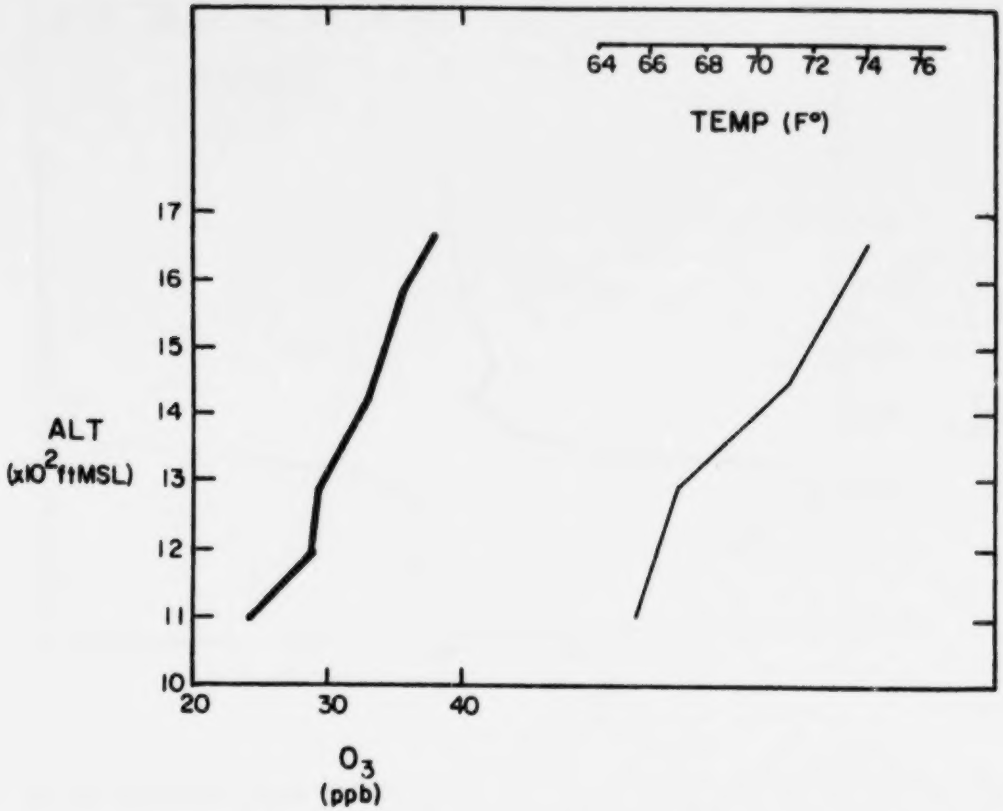


Figure B20. Plot of ozone and temperature data recorded during a vertical spiral 8 miles east of Benicia on September 10, 1975.

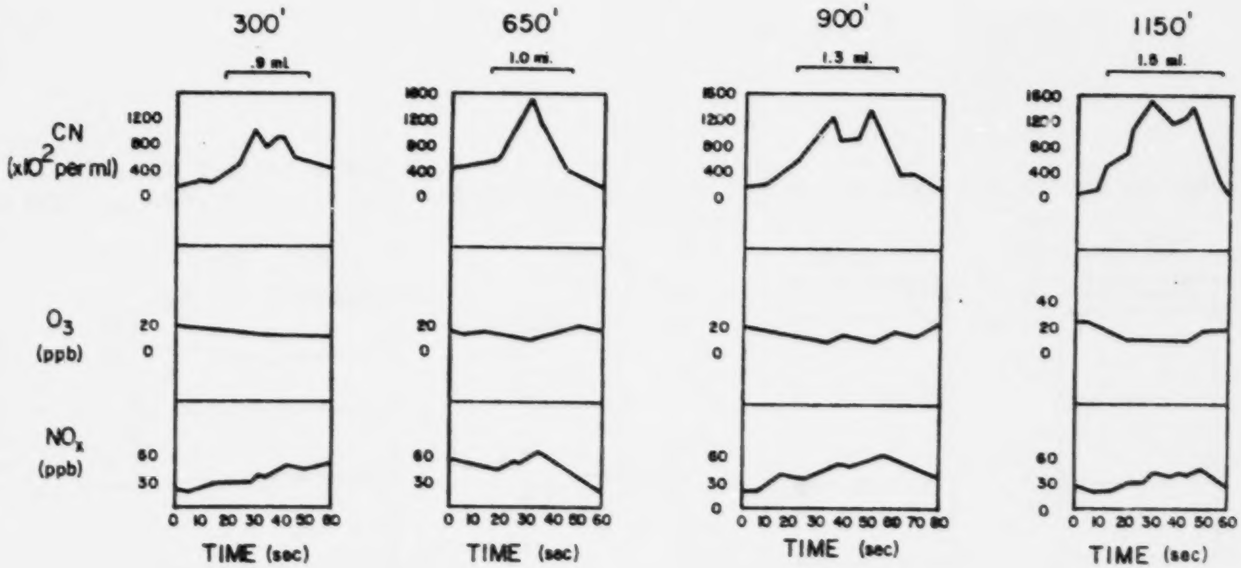


Figure B21. Plot of aircraft data recorded on September 10 during traverses of the refinery plume 5 miles downwind.

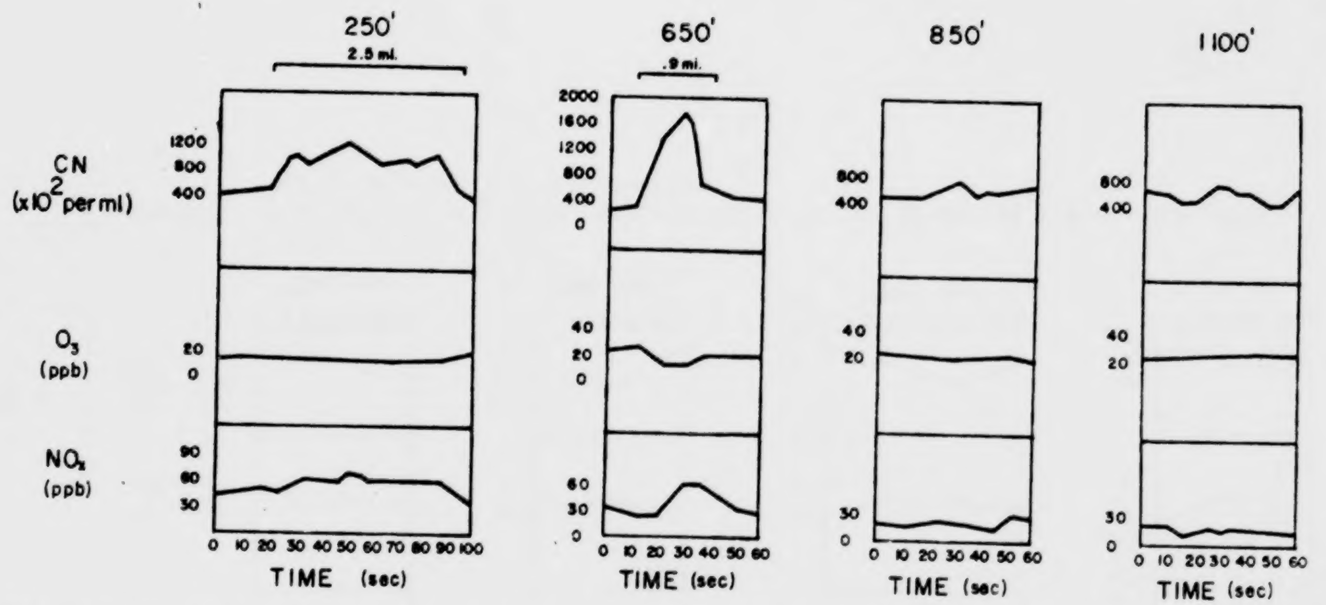


Figure B22. Plot of aircraft data recorded on September 10 during traverses of the refinery plume 8 miles downwind.

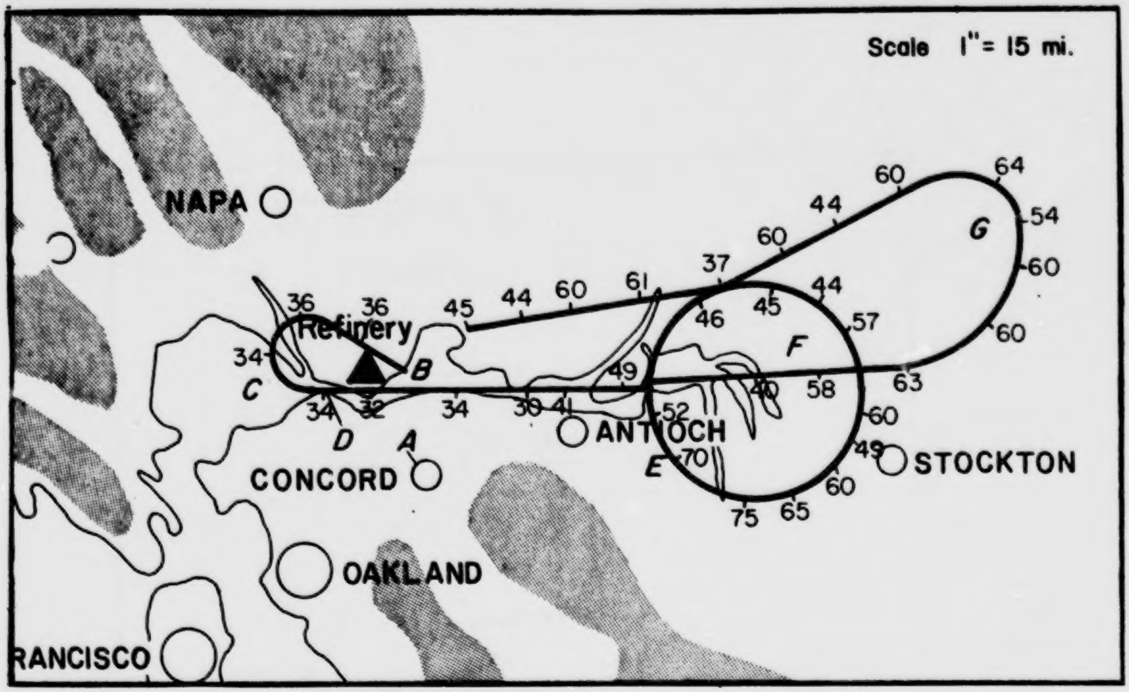

Scale 1" = 15 mi.
NAPA
Refinery
CONCORD
ANTIOCH
STOCKTON
OAKLAND
RANCISCO
A
B
C
D
E
F
G
36
36
34
34
32
34
30
41
45
44
60
61
37
60
44
60
64
54
60
60
63
46
45
44
57
49
40
58
52
70
75
65
60
49
60

Figure B23. Flight path on September 10, 1975, with ozone concentrations (ppb) marked along the route.

TIME: 4:25 PM - 6:55 PM

LEG
- A- Buchanan Field, climb to 1,000 feet
- B- Spiral up to 6,000 feet and down to 500 feet
- C- Upwind loop at 1,200 feet
- D- Rodeo, descend to 800 feet
- E- Begin 360 degree arc
- F- Spiral up to 4,500 feet and down to 800 feet
- G- Long downwind loop

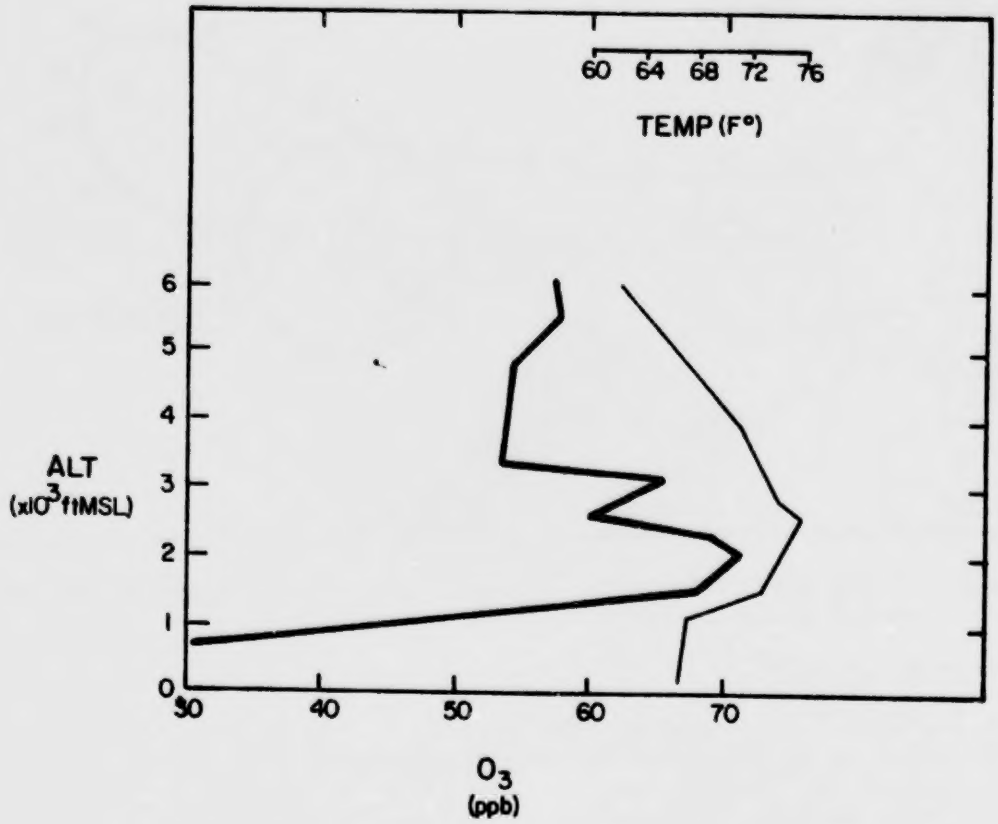


Figure B24. Plot of ozone and temperature data recorded during a vertical spiral over the WSU trailer on September 10, 1975.

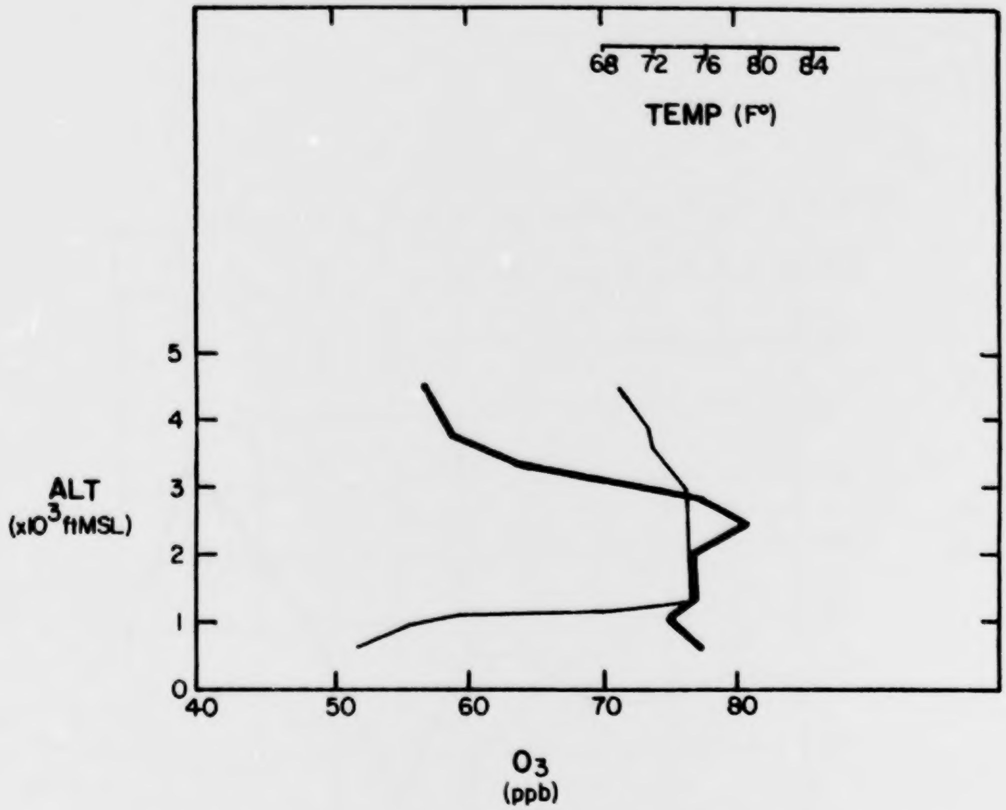


Figure B25. Plot of ozone and temperature data recorded during a vertical spiral 45 miles east of Benicia on September 10, 1975.

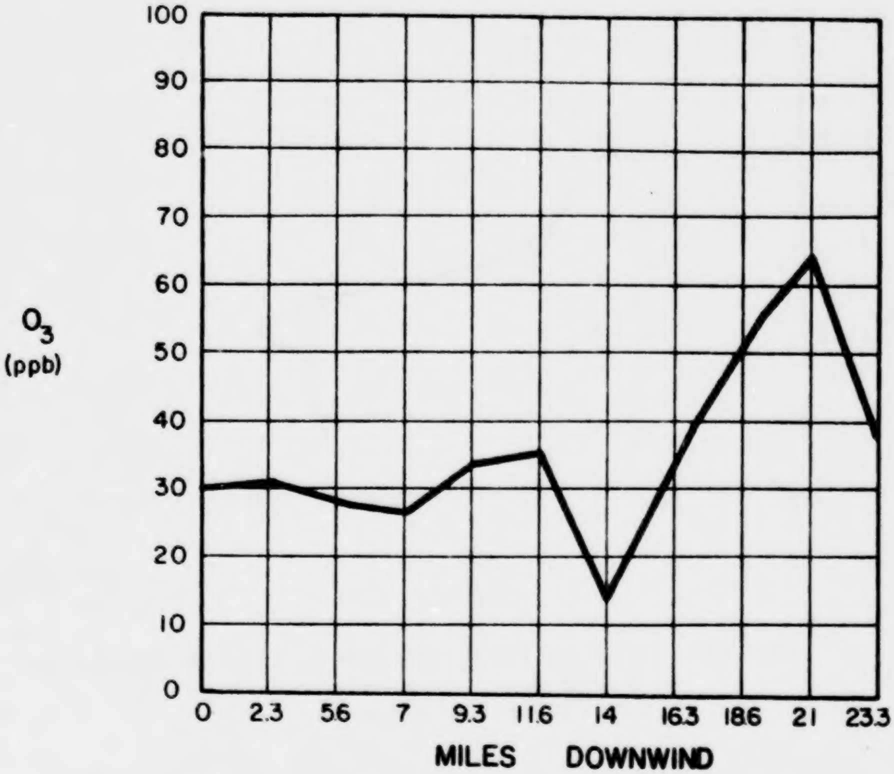


Figure B26. Plot of ozone concentration versus distance downwind of Benicia on September 10, 1975.

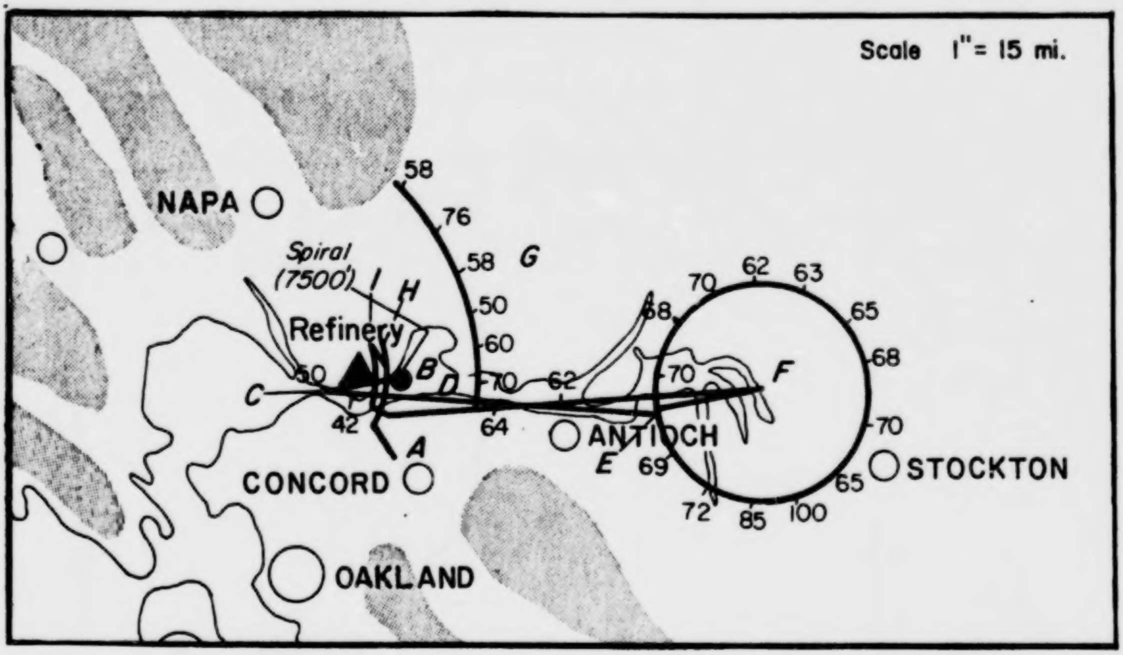

Scale 1" = 15 mi.
NAPA
58
76
58
G
50
60
70
62
64
Spiral (7500')
I
H
Refinery
B
D
C
50
42
A
CONCORD
OAKLAND
ANTIOCH
E
69
68
70
70
62
63
65
68
70
65
100
85
72
F
STOCKTON

Figure B27. Flight path on September 11, 1975, with ozone concentrations (ppb) marked along the route.

TIME: 4:35 PM - 6:55 PM

LEG A- Buchanan Field, climb to 1,00 feet
B- Spiral up to 6,700 feet and down to 500 feet
C- Upwind leg
D- Fly down plume at 1,000 feet
E- Begin 360 degree downwind arc
F- Spiral up to 6,000 feet and down to 1,000 feet
G- 10 mile arc at 1,000 feet
H- 2 mile arcs at 1,000 feet and 500 feet
I- 1 mile arcs at 500 feet and 1,000 feet

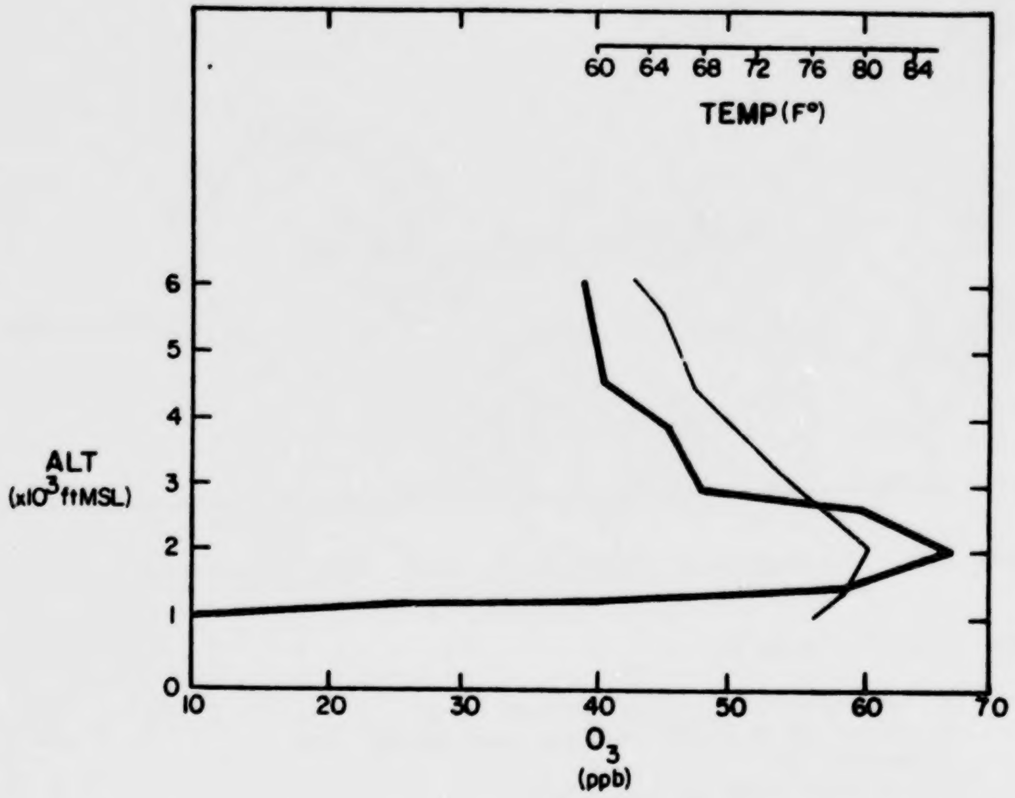


Figure B28. Plot of ozone and temperature data recorded during a vertical spiral over the WSU trailer on September 11, 1975.

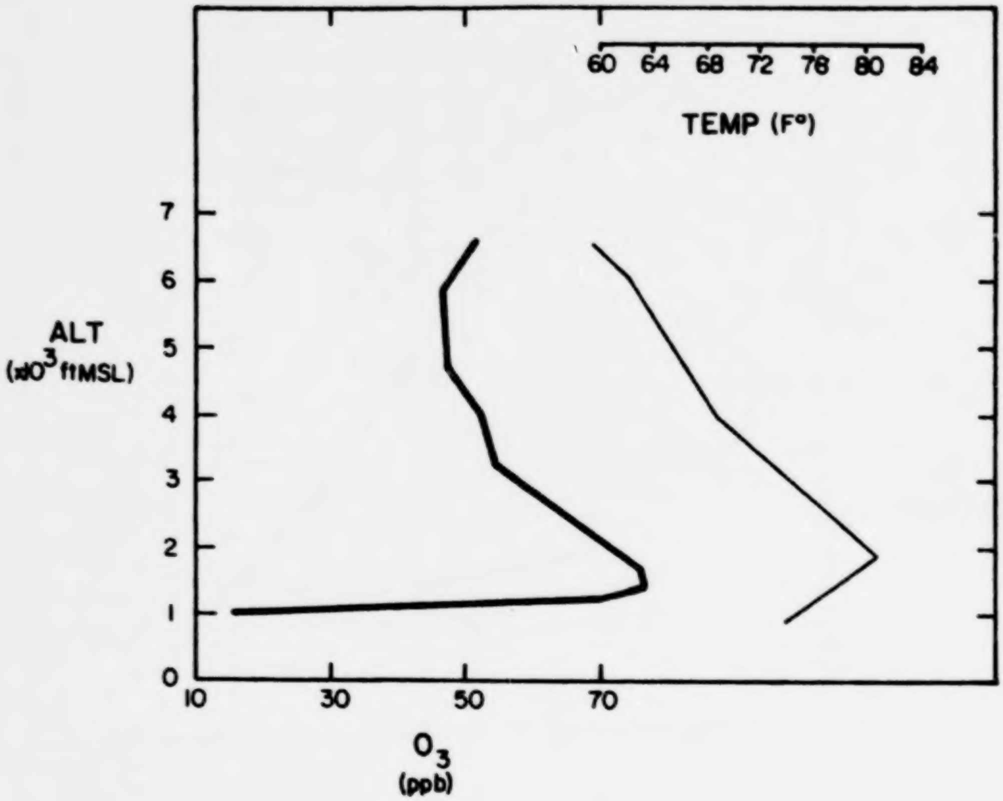


Figure B29. Plot of ozone and temperature data recorded during a vertical spiral over the WSU trailer on September 11, 1975.

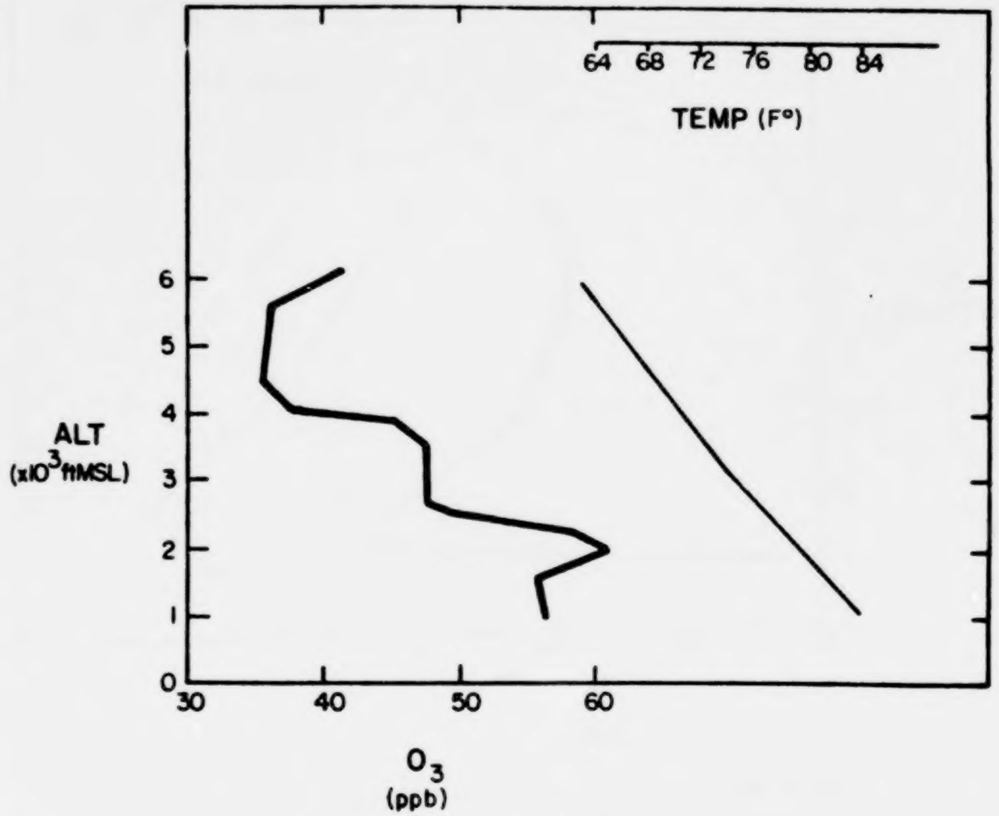


Figure B30. Plot of ozone and temperature data recorded during a vertical spiral 45 miles east of Benicia on September 11, 1975.

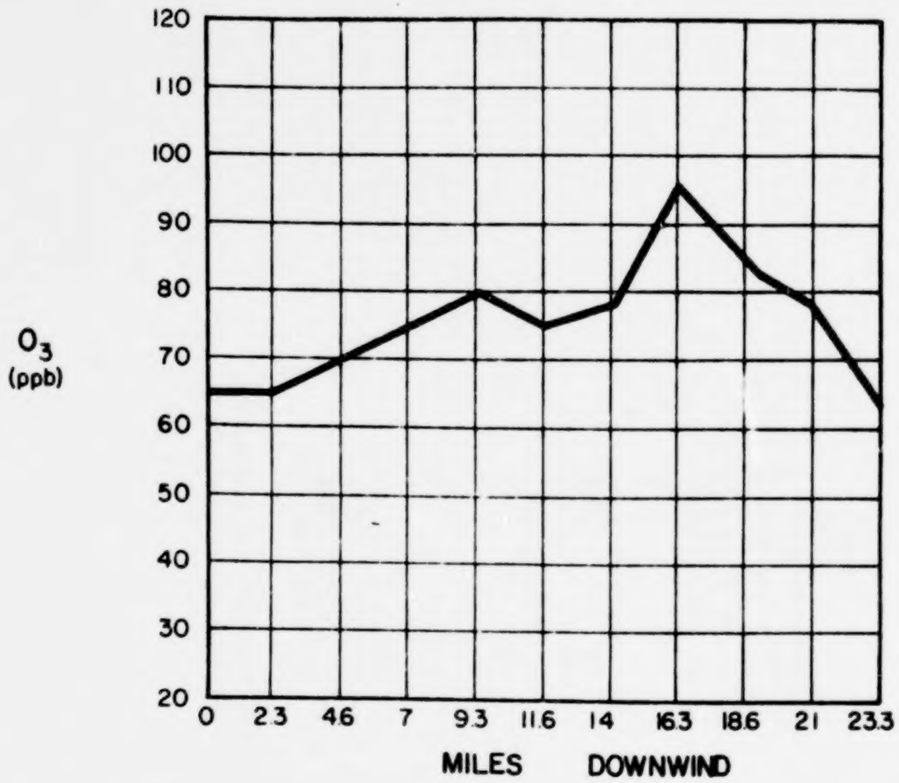


Figure B31. Plot of ozone concentration versus distance downwind of Benicia on September 11, 1975.

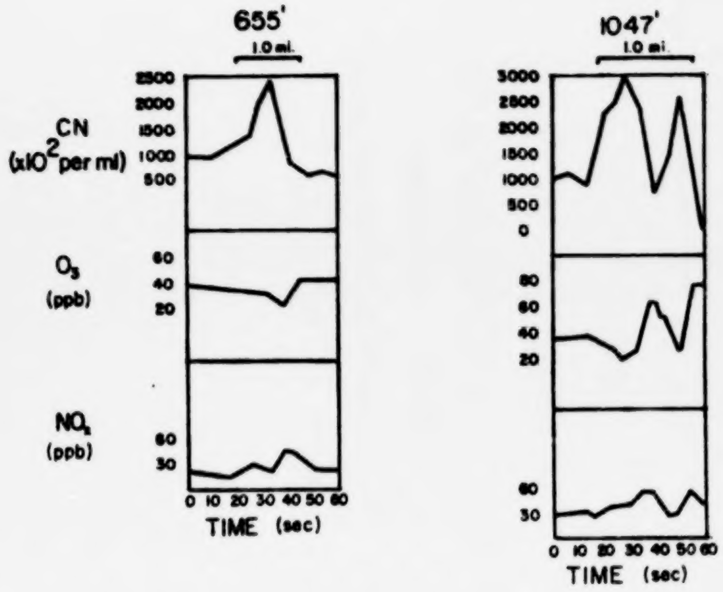


Figure B32. Plot of aircraft data recorded on September 11 during traverses of the refinery plume 1 mile downwind.

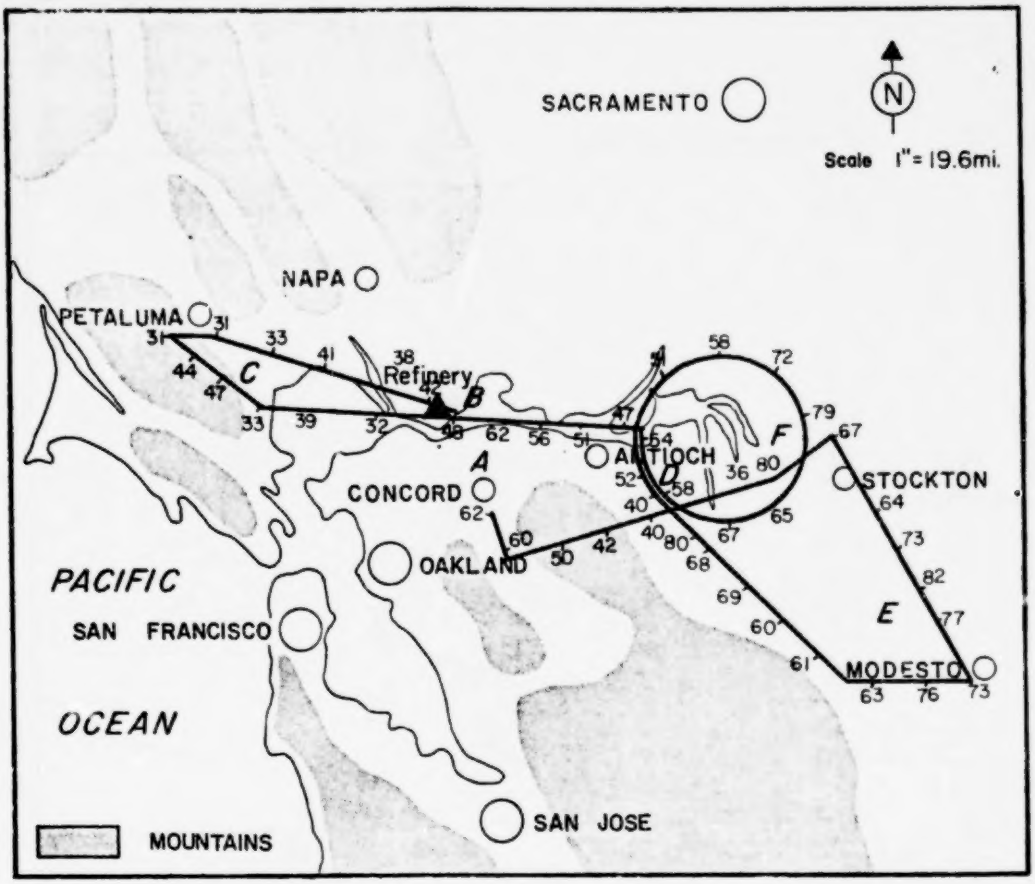

SACRAMENTO
N
Scale 1"= 19.6mi.
NAPA
PETALUMA
Refinery
CONCORD
ANTIOCH
STOCKTON
OAKLAND
PACIFIC
OCEAN
SAN FRANCISCO
MODESTO
SAN JOSE
MOUNTAINS
A
B
C
D
E
F

Figure B33. Flight path on September 12, 1975, with ozone concentrations (ppb) marked along the route.

TIME: 2:20 PM - 5:40 PM

LEG A- Buchanan Field, climb to 1,000 feet
B- Spiral up to 10,000 feet and down to 500 feet
C- Upwind loop at 1,000 feet
D- 360 degree arc of Franks Track Recreation Area
E- Long downwind loop
F- Spiral up to 10,000 feet, slant descent to A

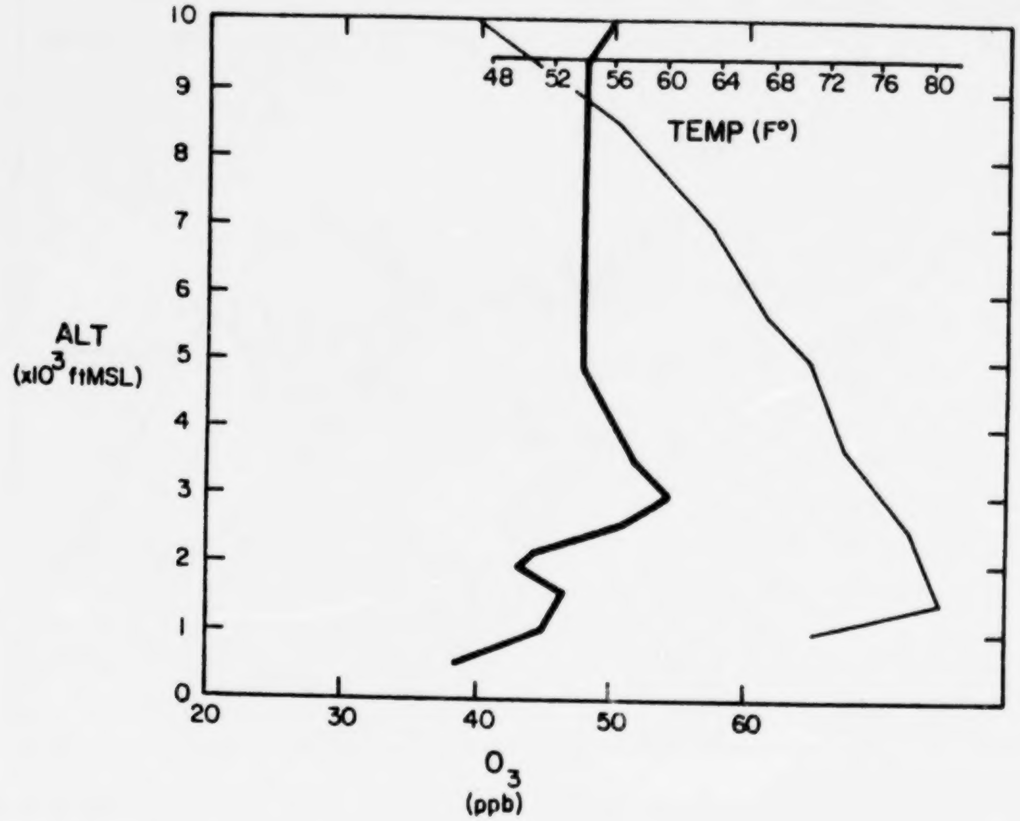


Figure B34. Plot of ozone and temperature data recorded during a vertical spiral over the WSU trailer on September 12, 1975.

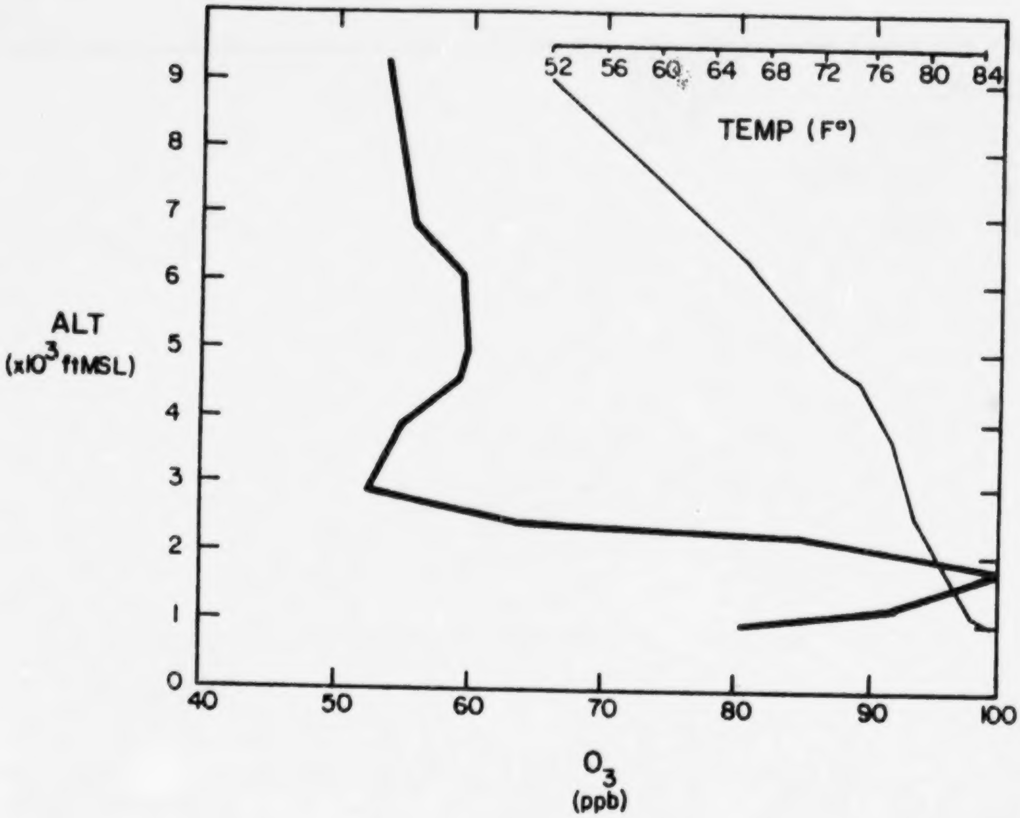


Figure B35. Plot of ozone and temperature data recorded during a vertical spiral 45 miles east of Benicia on September 12, 1975.

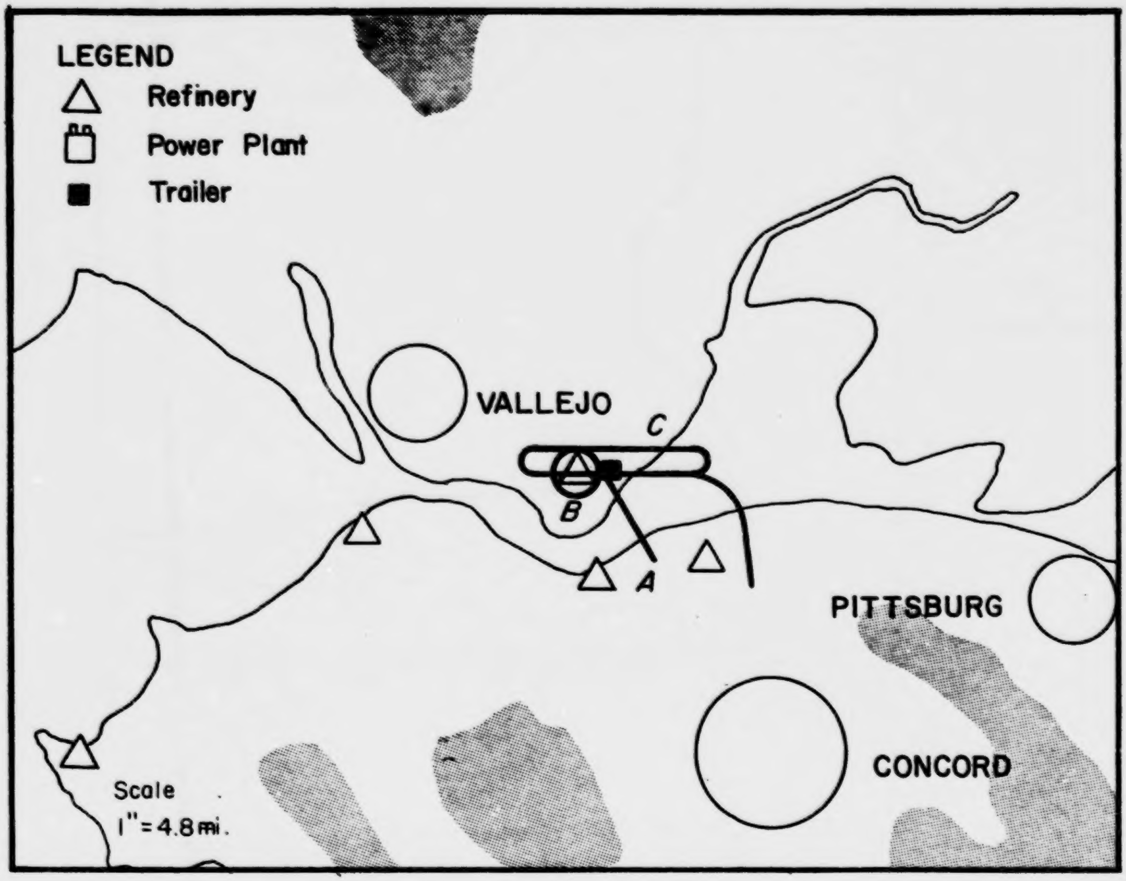

LEGEND
△ Refinery
Power Plant
■ Trailer
VALLEJO
C
B
A
PITTSBURG
CONCORD
Scale
1"=4.8 mi.

Figure B36. Flight path on September 13, 1975.

TIME: 1:35 PM - 2:25 PM

LEG A- Buchanan Field, climb to 1,000 feet
B- 1 mile arc of refinery
C- 2 racetrack patterns at 1,000 feet and 500 feet

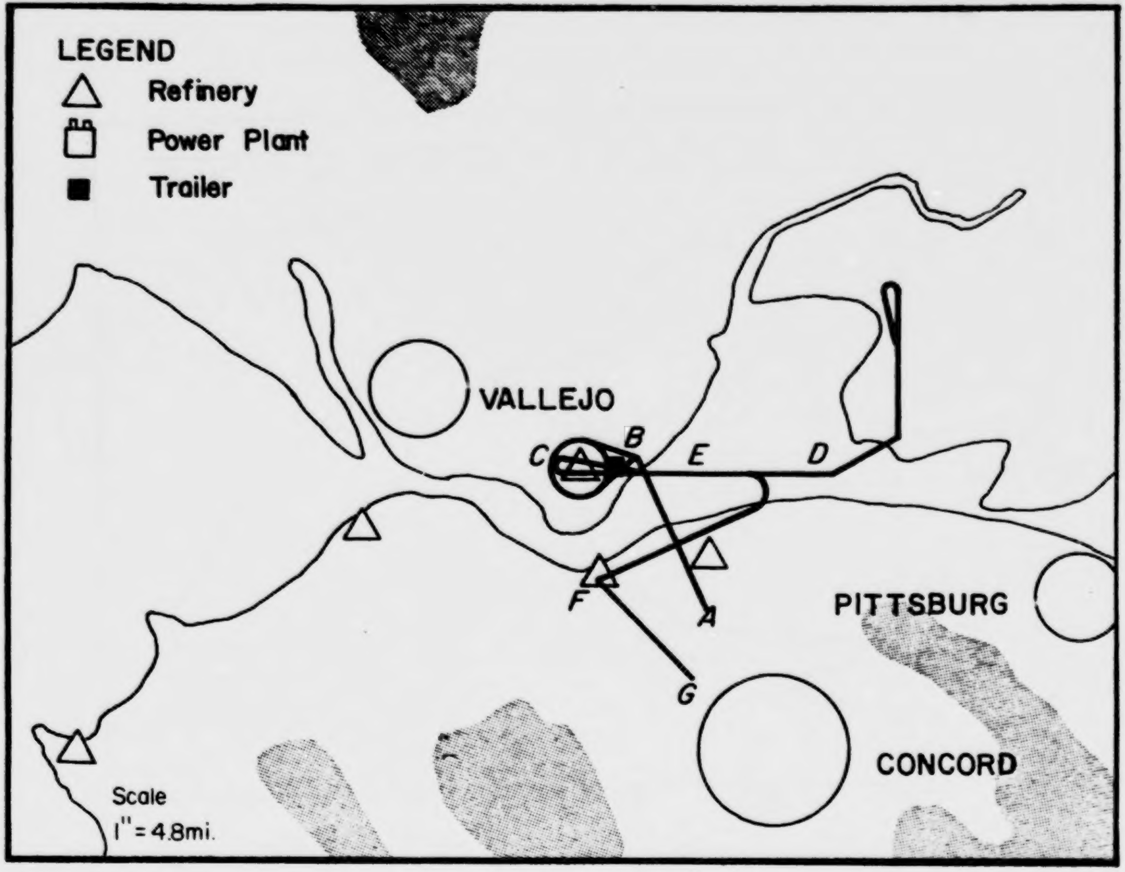

LEGEND
△ Refinery
Power Plant
■ Trailer
VALLEJO
PITTSBURG
CONCORD
A
B
C
D
E
F
G
Scale
1" = 4.8mi.

Figure B37. Flight path on September 13, 1975.

TIME: 3:50 PM - 5:15 PM

LEG A- Buchanan Field, climb to 1,000 feet, circle refinery once to B
B- Spiral up to 6,000 feet and down to 500 feet
C- 1 mile arcs of refinery, 2½ loops
D- Fly downwind and return in visible plume at 1,000 feet
E- Fly down visible plume at 500 feet
F- Shell refinery, climb to 13,00 feet, fly down visible plume
G- Return to A

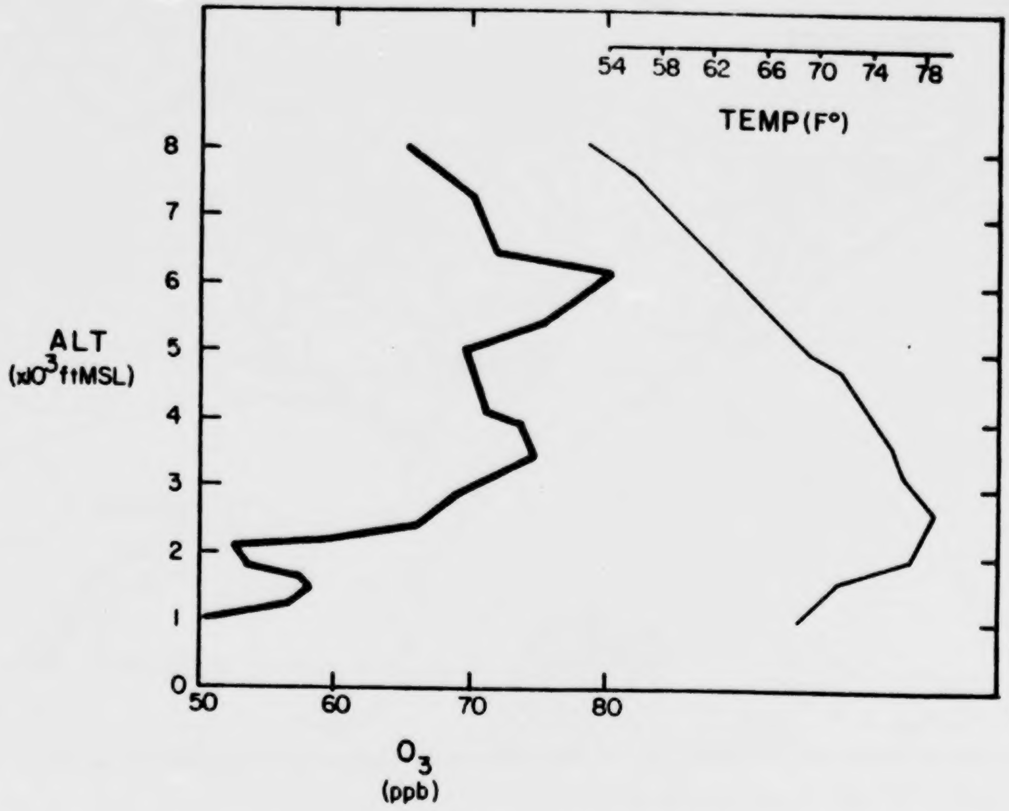


Figure B38. Plot of ozone and temperature data recorded during a vertical spiral over the WSU trailer on September 13, 1975.

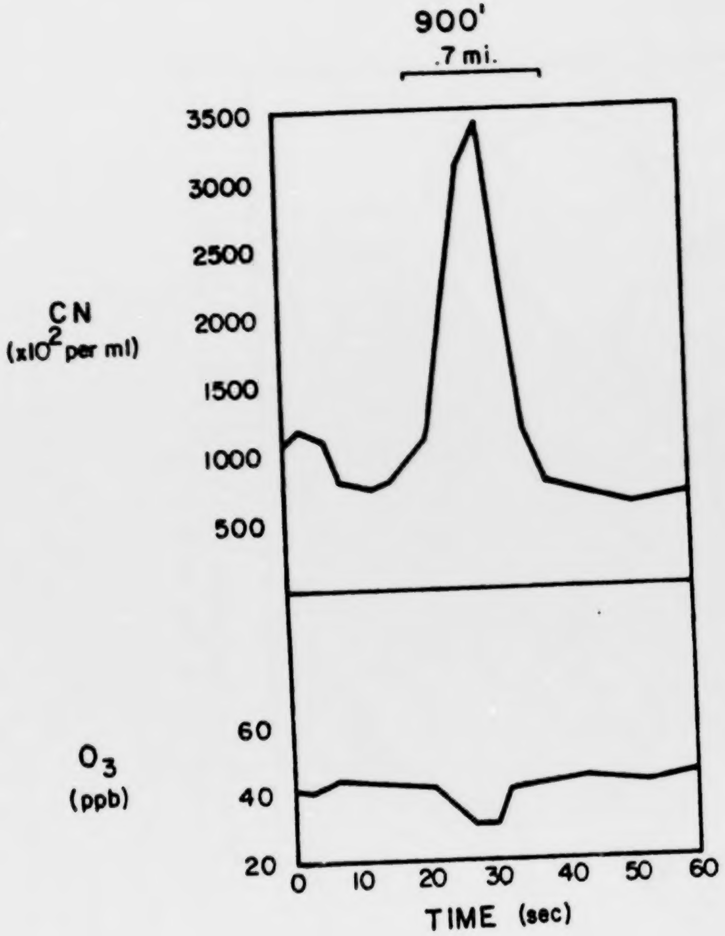


Figure B39. Plot of aircraft data recorded on September 13 during a traverse of the refinery plume 1 mile downwind at 900 ft. AGL.

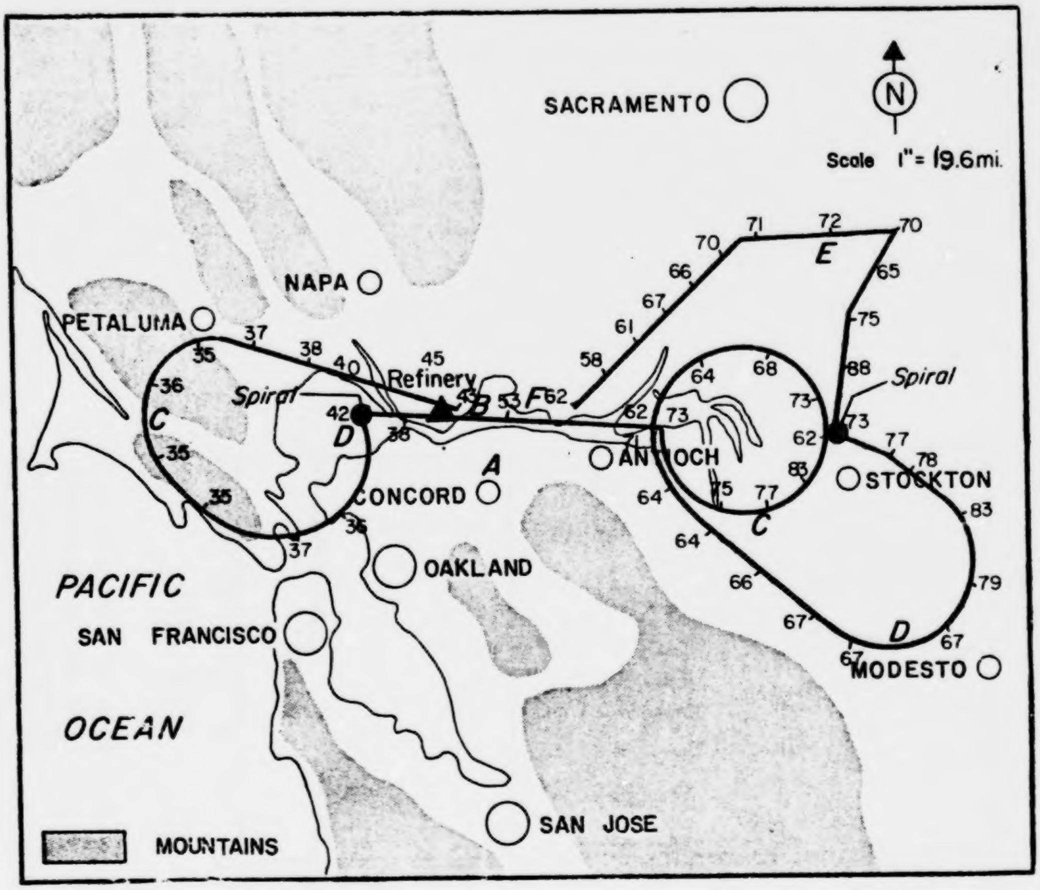

SACRAMENTO
N
Scale 1"= 19.6mi.
NAPA
PETALUMA
37
38
40
45
Refinery
43
B
53
F
62
58
61
67
66
70
71
72
E
70
65
75
88
Spiral
73
77
78
83
79
67
D
67
MODESTO
35
36
C
35
35
37
36
Spiral
42
D
38
A
CONCORD
OAKLAND
64
68
73
62
73
ANTIOCH
62
83
64
75
77
C
64
66
67
STOCKTON
PACIFIC
SAN FRANCISCO
OCEAN
SAN JOSE
MOUNTAINS

Figure B40. Flight paths on September 14, 1975, with ozone concentrations (ppb) marked along the route.

TIME: 1:05 PM - 3:05 PM

LEG
A- Buchanan Field, climb to 1,000 feet
B- Spiral up to 11,000 feet and down to 500 feet
C- Long upwind loop at 1,000 feet
D- Spiral up to 5,000 feet and down to 1,200 feet

TIME: 3:35 PM - 6:25 PM

LEG
A- Buchanan Field, climb to 2,000 feet, descend to 1,000 feet
B- Fly down plume
C- 360 degree arc of Franks Track
D- Southern downwind loop
E- Northern downwind loop
F- Fly up plume

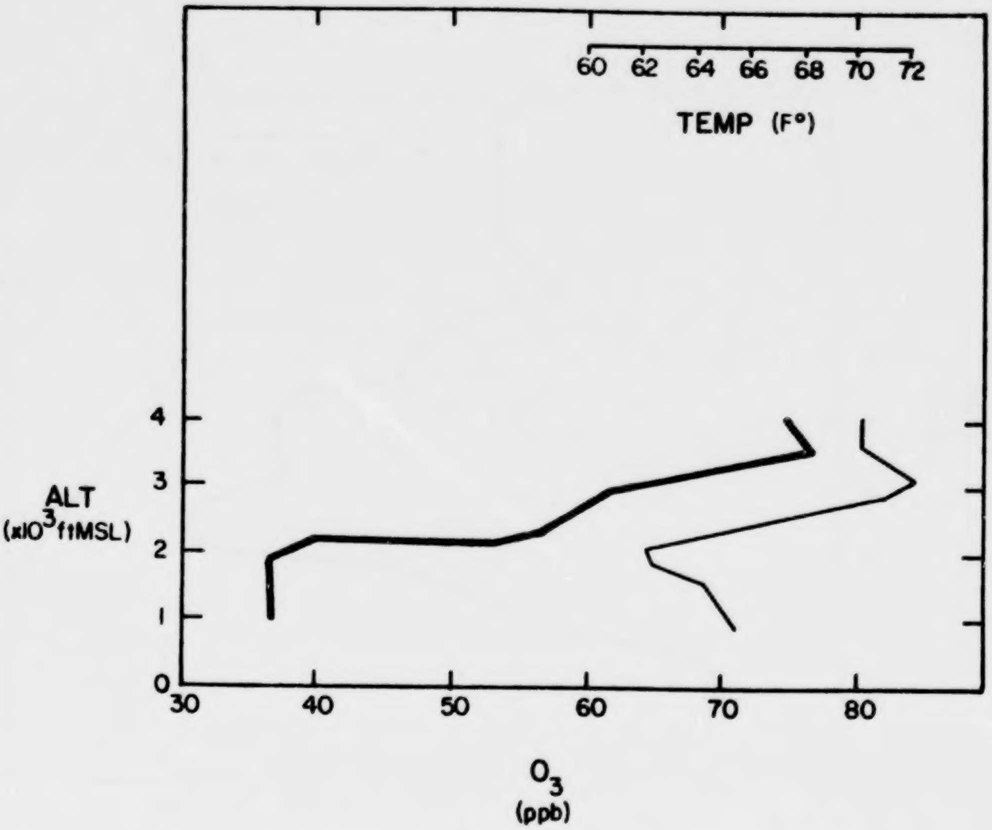


Figure B41. Plot of ozone and temperature data recorded during a vertical spiral over San Pablo Bay on September 14, 1975.

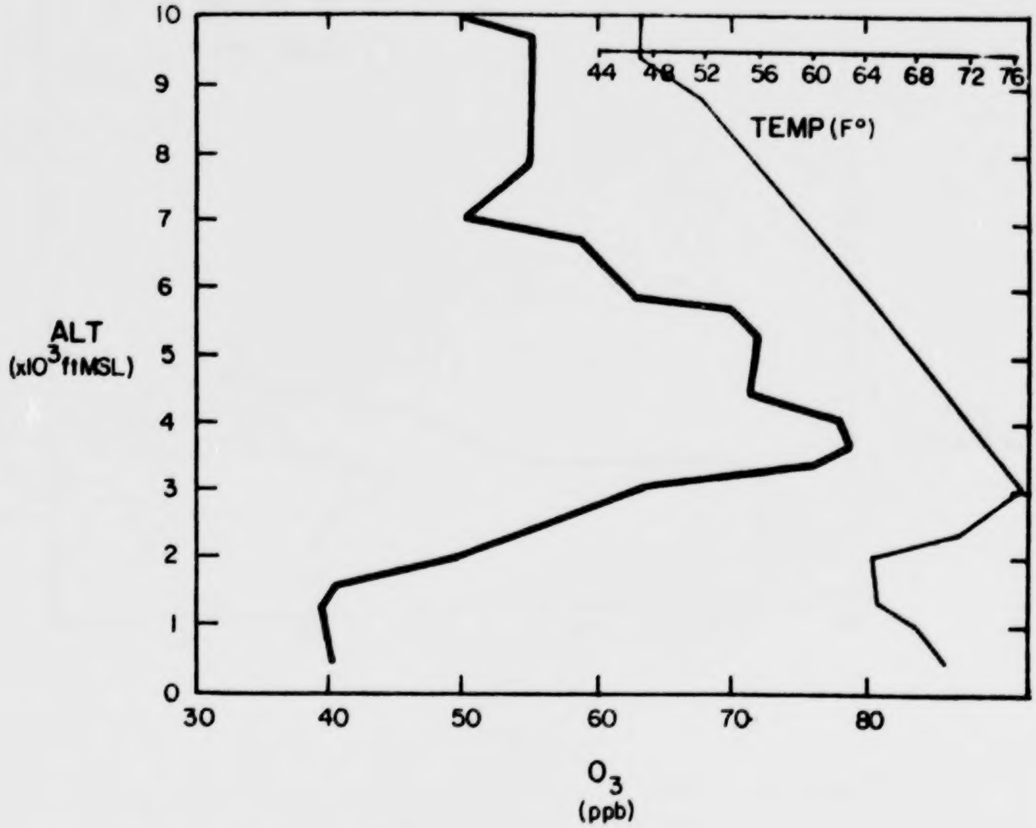


Figure B42. Plot of ozone and temperature data recorded during a vertical spiral over the WSU trailer on September 14, 1975.

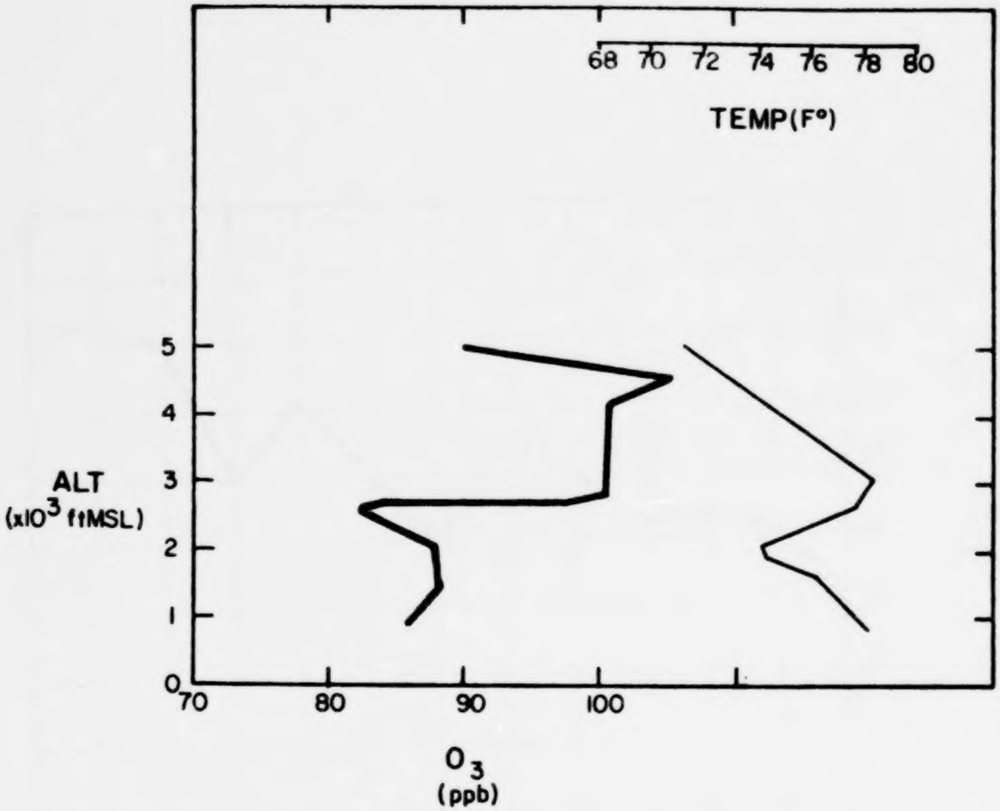


Figure B43. Plot of ozone and temperature data recorded during a vertical spiral over Stockton on September 14, 1975.

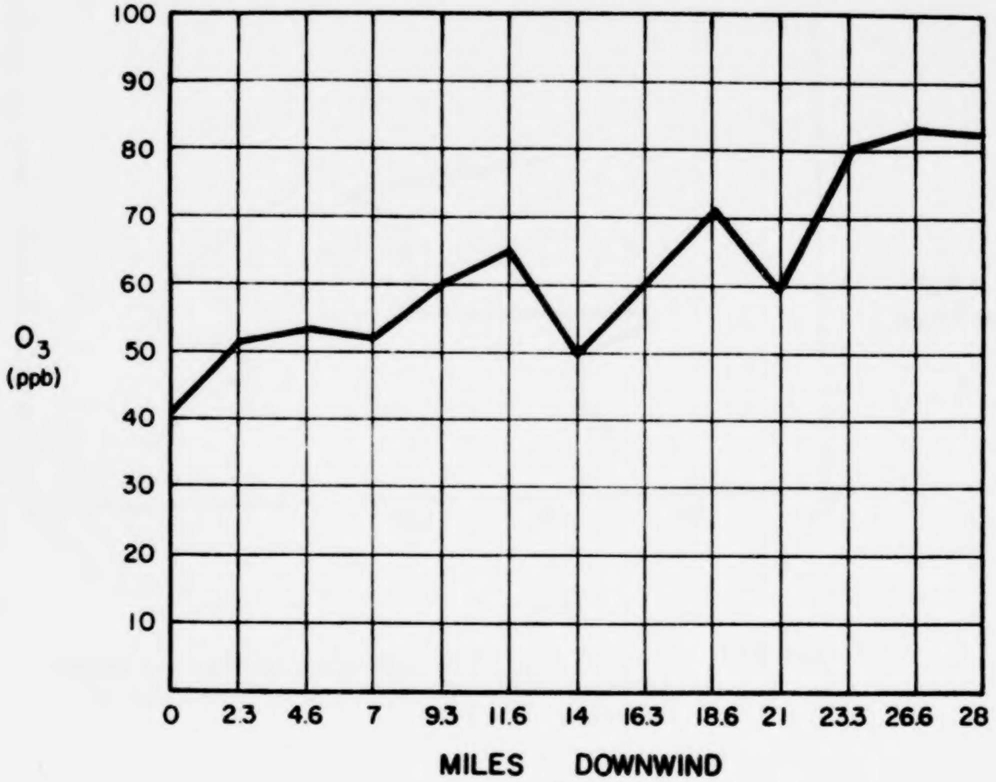


Figure B44. Plot of ozone concentration versus distance downwind of Benicia on September 14, 1975.

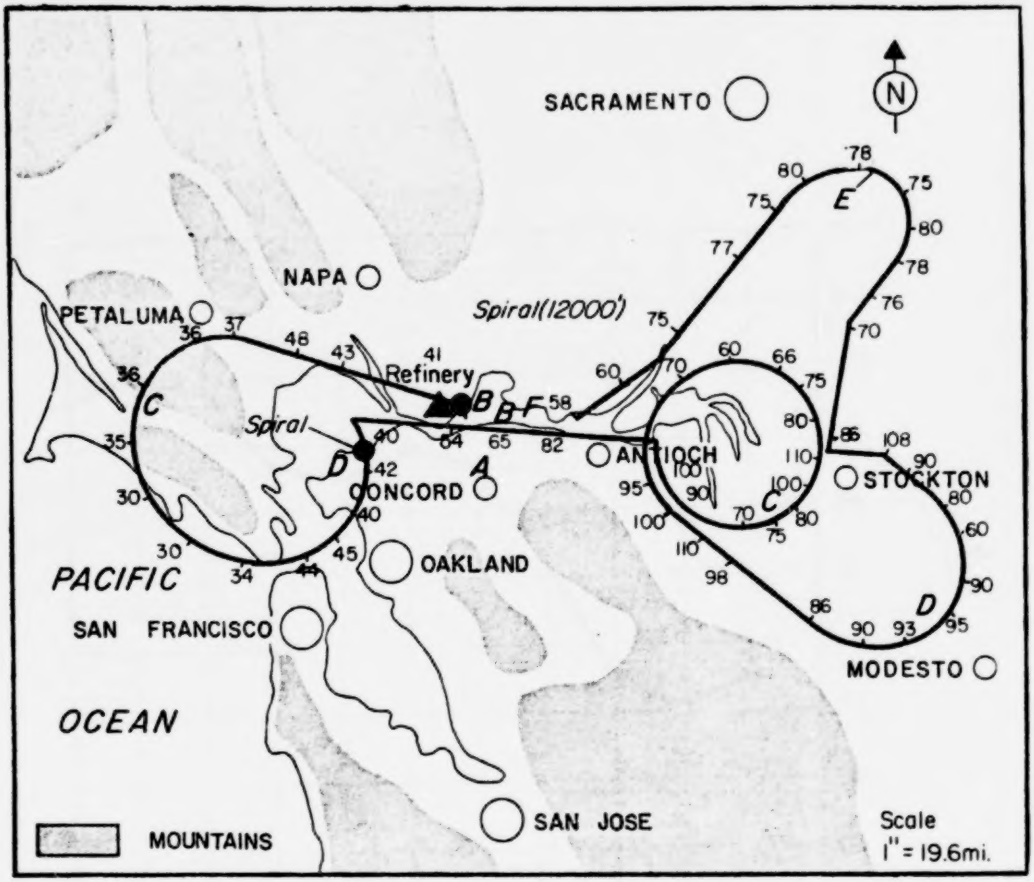

N
SACRAMENTO
NAPA
PETALUMA
Spiral(12000')
Refinery
Spiral
CONCORD
ANTIOCH
STOCKTON
OAKLAND
PACIFIC
OCEAN
SAN FRANCISCO
MODESTO
SAN JOSE
MOUNTAINS
Scale
1" = 19.6mi.
A
B
B
C
C
D
D
E
F
36
37
48
43
41
36
35
30
30
34
44
45
40
40
42
64
65
82
58
60
70
75
77
75
80
78
75
80
78
76
70
86
108
90
80
60
90
95
93
90
86
98
110
100
95
100
90
70
75
80
100
110
80
75
66
60

Figure B45. Flight paths on September 15, 1975, with ozone concentrations (ppb) marked along the route.

TIME: 1:20 PM - 3:20 PM

LEG
A- Buchanan Field, climb to 1,000 feet
B- Spiral up to 12,000 feet and down to 500 feet
C- Upwind loop at 1,000 feet
D- Spiral up to 5,000 feet and down to 500 feet

TIME: 3:35 PM - 5:55 PM

LEG
A- Buchanan Field, climb to 1,000 feet
B- Fly down visible plume
C- 360 degree arc of Franks Track
D- Southern downwind loop
E- Northern downwind loop
F- Fly up plume

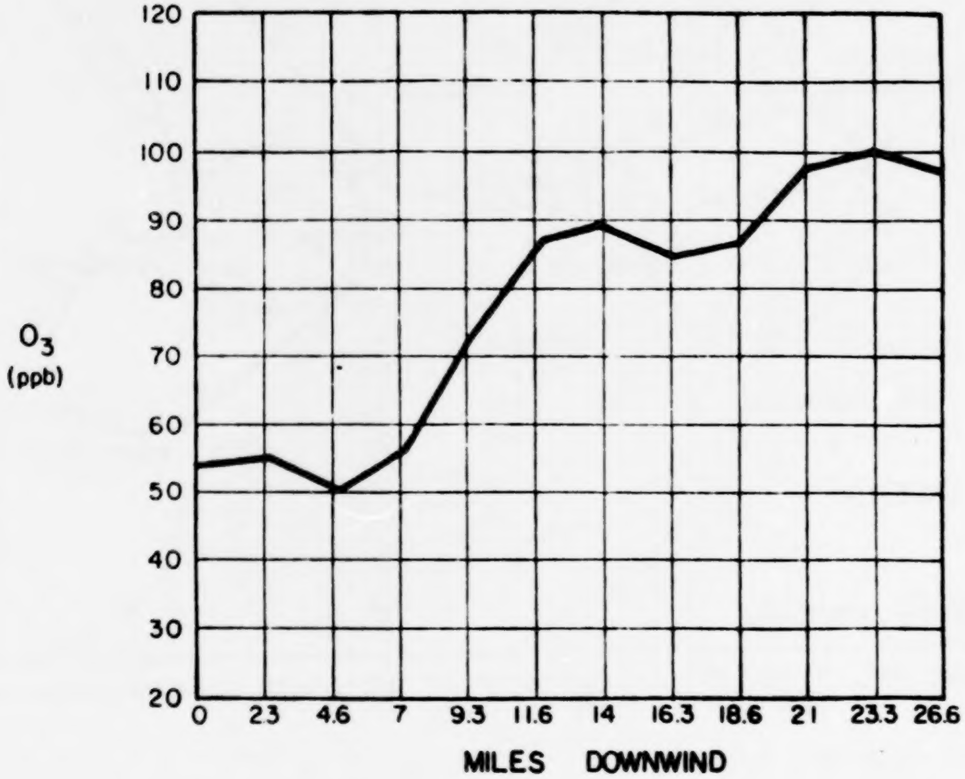


Figure B46. Plot of ozone concentrations versus distance downwind of Benicia on September 15, 1975.

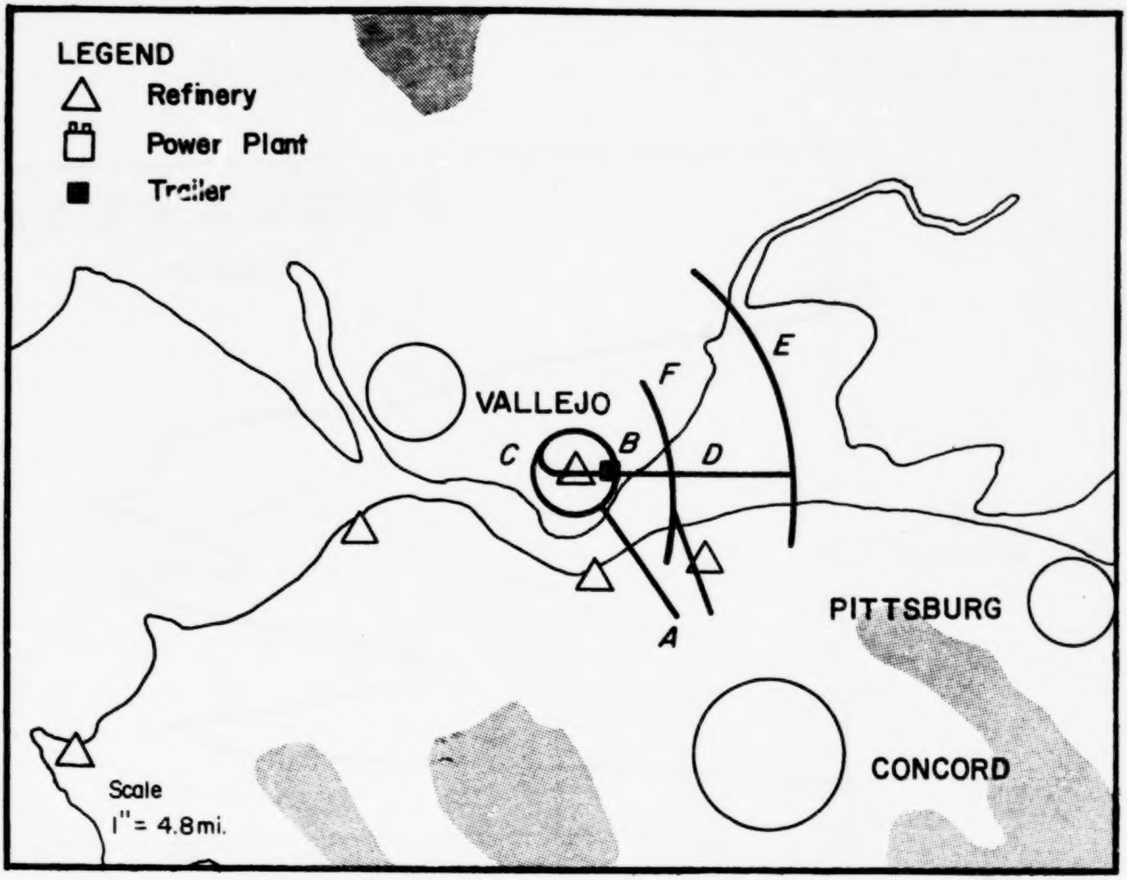

LEGEND
△ Refinery
Power Plant
■ Trailer
VALLEJO
PITTSBURG
CONCORD
A
B
C
D
E
F
Scale
1" = 4.8mi.

Figure B47. Flight path on September 16, 1975.

TIME: 11:25 PM - 12:50 PM

LEG	
A-	Buchanan Field, climb to 1,000 feet
B-	Spiral up to 8,000 feet and down to 500 feet
C-	2 mile arc of refinery at 1,000 feet
D-	Fly downwind with plume
E-	6 mile refinery arcs at 500 feet, 250 feet, 750 feet, and 1,000 feet
F-	3 mile refinery arcs at 750 feet, 500 feet, 1,000 feet, and 1,200 feet

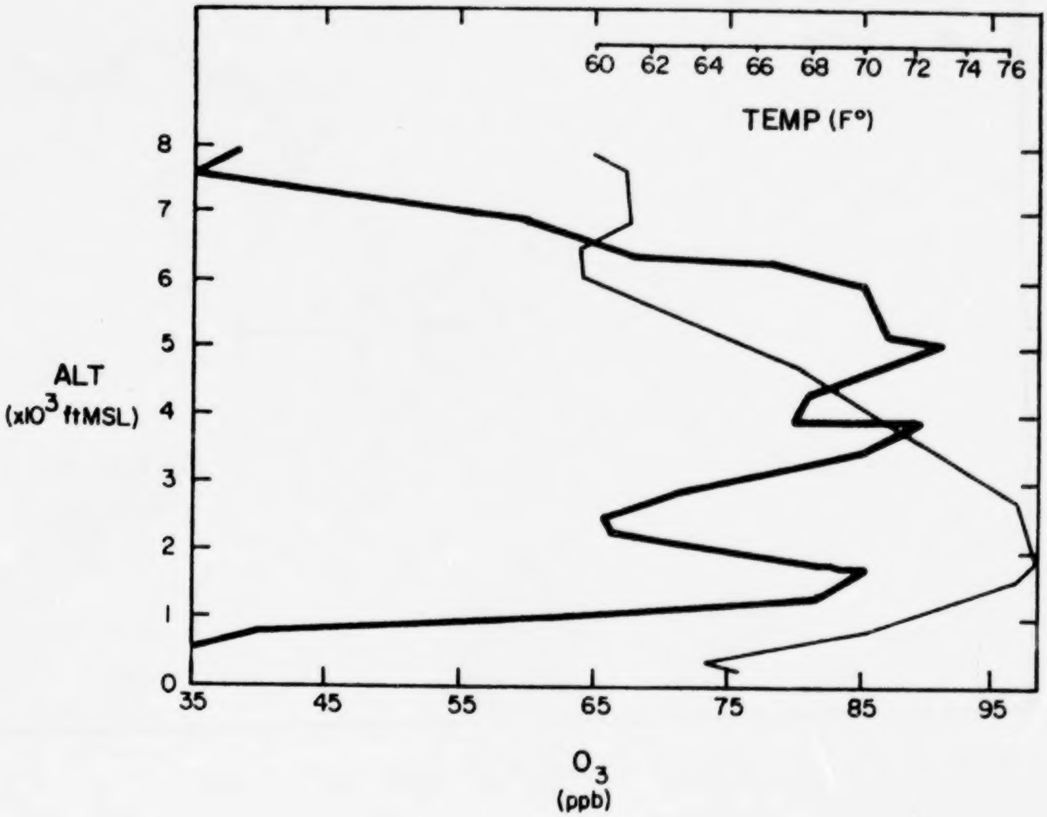


Figure B48. Plot of ozone and temperature data recorded during a vertical spiral over the WSU trailer on September 16, 1975.

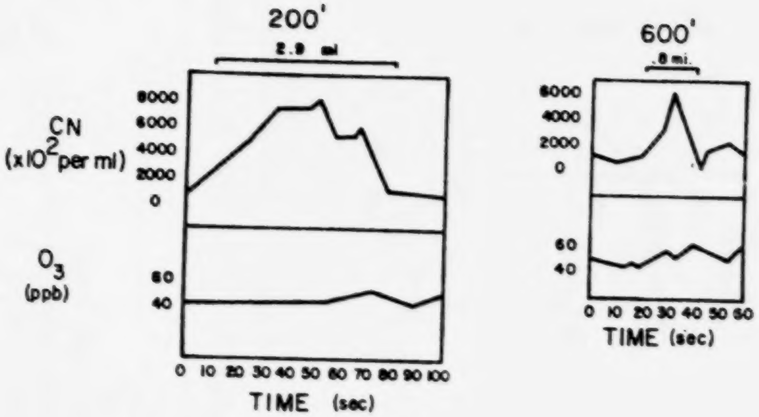
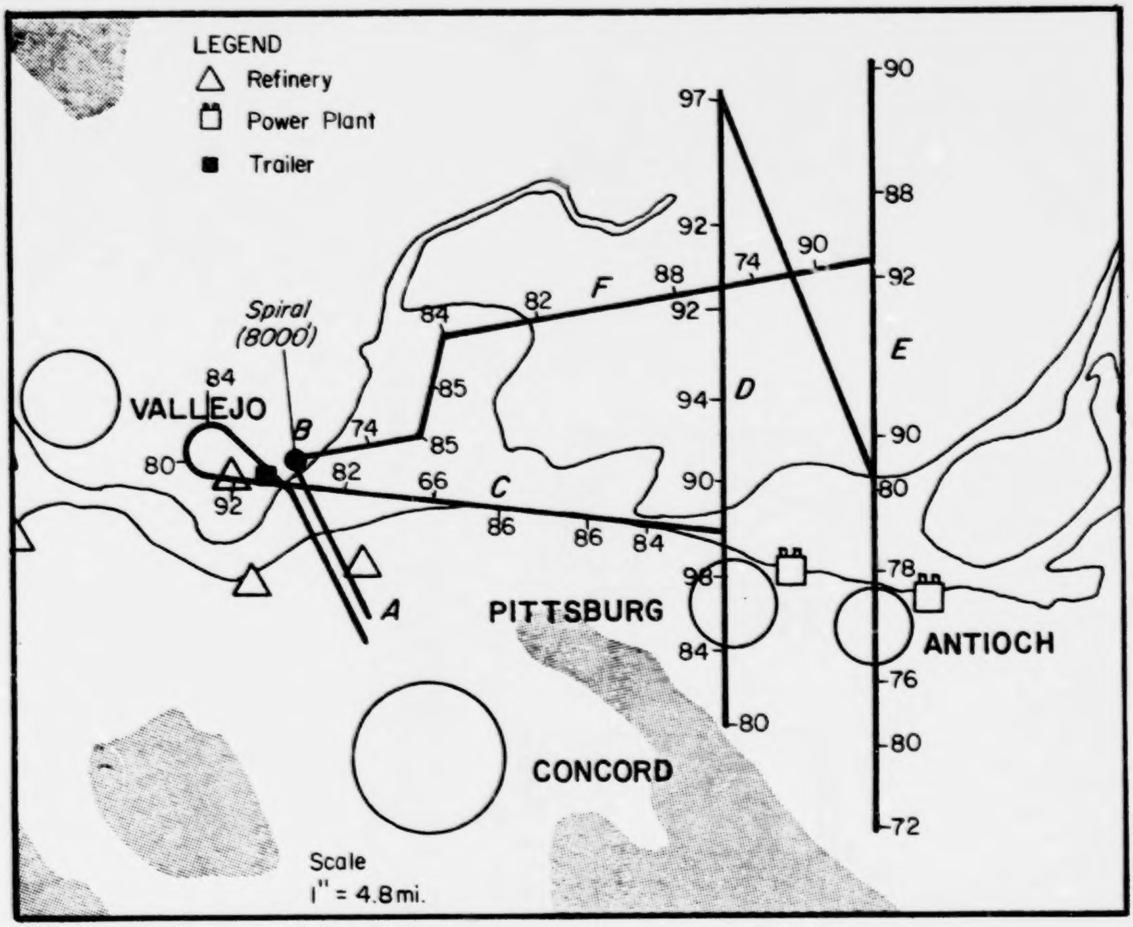


Figure B49. Plot of aircraft data recorded on September 16 during traverses of the refinery plume 6 miles downwind.


LEGEND
△ Refinery
Power Plant
■ Trailer
Spiral
(8000')
VALLEJO
PITTSBURG
ANTIOCH
CONCORD
Scale
1" = 4.8 mi.
A
B
C
D
E
F
84
80
92
74
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94
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98
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80
90
88
92
90
80
78
76
80
72

Figure B50. Flight path on September 16, 1975, with ozone concentrations (ppb) marked along the route.

TIME: 4:30 PM - 6:20 PM

LEG
- A- Buchanan Field, climb to 1,000 feet
- B- Spiral up to 8,000 feet and down to 500 feet
- C- Fly down southern edge of plume
- D- 14 mile cross-plume pass
- E- 18 mile cross-plume pass
- F- Fly up northern edge of plume

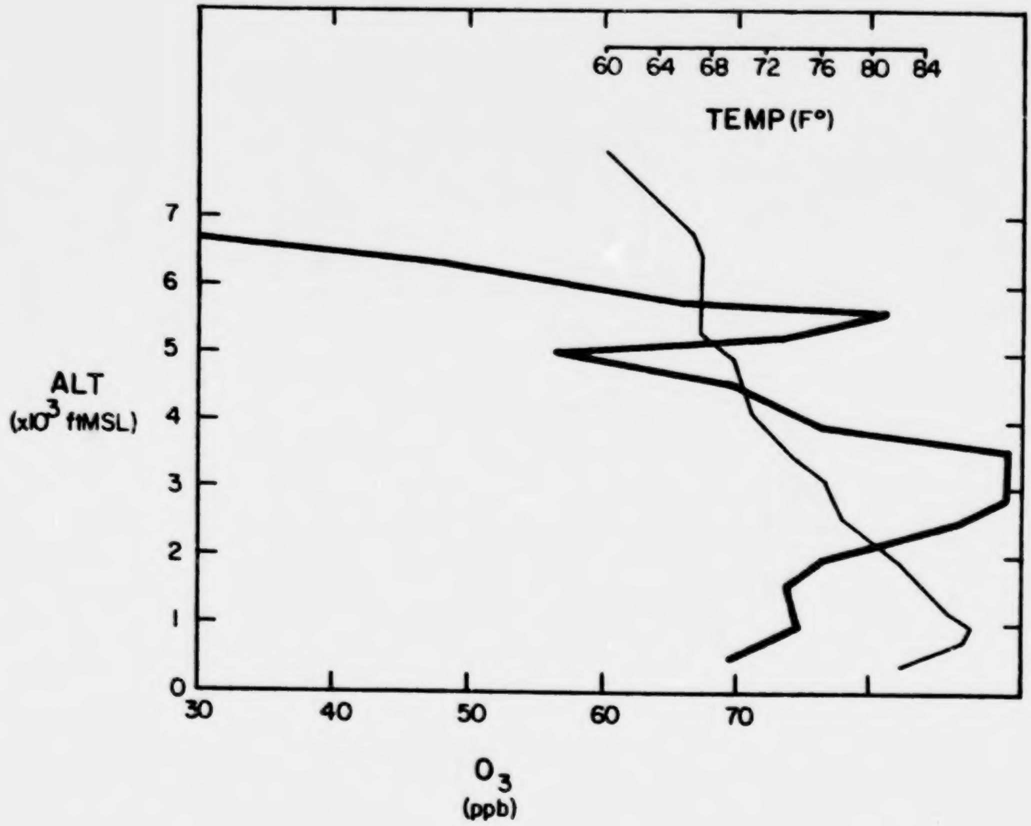

Figure B51. Plot of ozone and temperature data recorded during a vertical spiral over the WSU trailer on September 16, 1975.

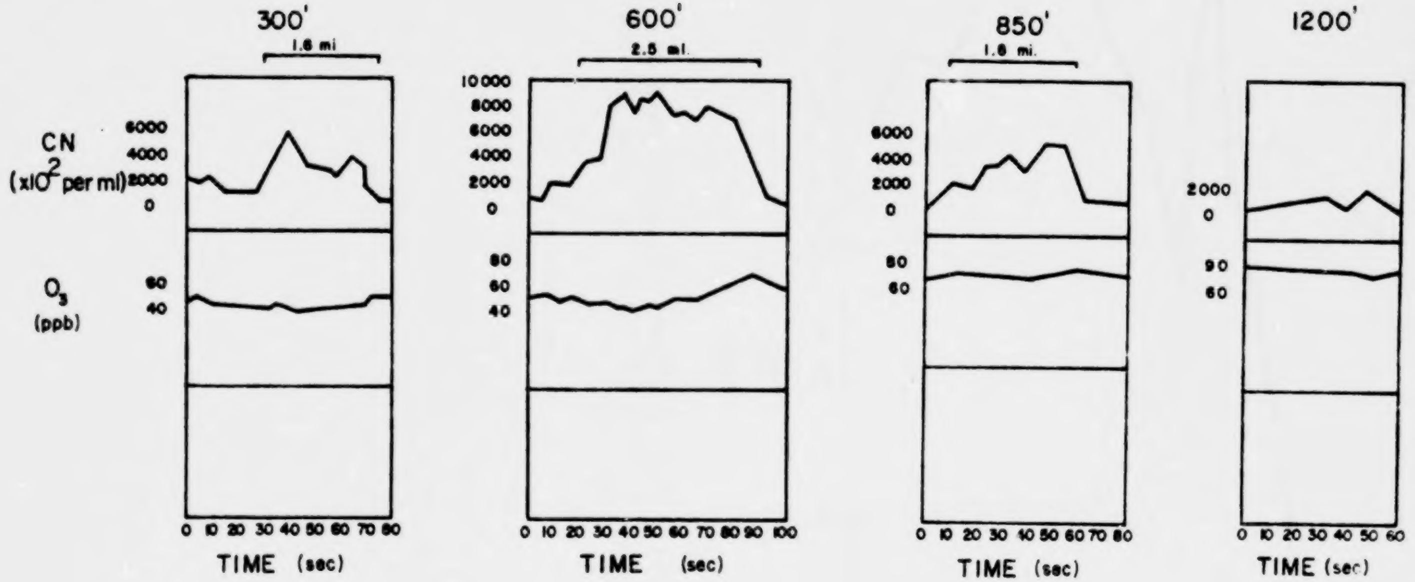

Figure B52. Plot of aircraft data recorded on September 16 during traverses of the refinery plume 3 miles downwind.

APPENDIX C

Individual light hydrocarbon (C_2-C_6) identification for all aircraft and ground level samples is given in this portion of the report. Results of CH_4, CO, $CFCl_3$ and CCl_4 analyses on selected samples are also provided. In each case, collection locations as well as altitude and time (where applicable) have been noted.

TABLE C1. LIGHT HYDROCARBON CONCENTRATIONS IN AIRCRAFT COLLECTED SAMPLES ON SEPTEMBER 8, 1975

	Concentration ($\mu g/m^3$)												
	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10	A-11	A-12	A-13
ethane	3.5	13.0	16.5	4.5	3.5	17.0	11.0						
ethylene	2.0	3.5	9.5	1.0	1.5	4.0	2.5						
acetylene	*	2.0	6.5	1.0	*	2.0	2.0						
propane	1.5	9.5	15.0	2.5	1.5	22.0	11.5						
propene	*	1.5	10.0	4.0	*	2.0	1.0						
i-butane	*	4.0	16.5	1.0	*	10.0	5.5						
n-butane	1.0	9.0	38.5	2.0	1.0	17.5	13.0						
1-butene	*	*	2.5	*	*	*	*						
i-butene	1.0	1.0	*	*	*	1.0	1.0						
t-2-butene	*	*	5.5	*	*	0.5	*						
propyne	*	*	*	*	*	*	*						
c-2-butene	*	*	3.0	*	*	*	*						
i-pentane	2.5	9.5	34.5	3.0	2.0	20.5	10.0						
n-pentane	1.0	3.5	14.5	0.5	1.0	7.0	3.5						
cyclopentane	*	*	*	*	*	*	*						
1-pentene	*	*	*	*	*	*	*						
i-hexane	1.0	2.5	-	-	-	-	1.0						
3-m-pentane	*	2.0	-	-	-	-	-						
n-hexane	*	1.5	-	-	-	-	-						
Σolefins	3.0	6.0	20.5	5.0	1.5	7.5	4.5						
Σparaffins	10.5	54.5	135.5	18.5	9.0	94.0	55.5						
Total $\mu g/m^3$	13.5	62.5	172.5	19.5	10.5	103.5	62.0						
Total ppm C	0.02	0.10	0.26	0.03	0.02	0.16	0.10						
CH_4 (ppm)	1.8	-	1.8	1.7	-	1.7	1.7						
CO (ppm)	1.3	-	1.2	0.5	-	0.8	0.7						
$CFCl_3$ (ppt)	-	-	-	-	-	-	-						
CCl_4 (ppt)	-	-	-	-	-	-	-						

* < 0.5 $\mu g/m^3$

- missing data

TABLE C2. LIGHT HYDROCARBON CONCENTRATIONS IN AIRCRAFT COLLECTED SAMPLES ON SEMPTEMBER 9, 1975

	Concentration ($\mu g/m^3$)												
	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10	A-11	A-12	A-13
ethane	4.5	5.0	19.0	26.5	41.5	4.0	4.0	8.5	9.0	6.5			
ethylene	1.0	1.5	3.0	3.0	5.5	*	2.0	3.5	2.5	1.5			
acetylene	*	1.5	2.0	1.5	2.0	*	*	2.5	2.5	1.0			
propane	2.0	2.5	12.0	21.0	32.0	3.0	1.5	7.0	12.5	9.0			
propene	*	*	1.0	1.5	1.5	*	1.5	1.0	2.0	1.0			
i-butane	1.0	1.5	5.5	8.5	11.0	*	*	3.5	6.5	5.5			
n-butane	1.5	2.5	8.5	13.0	17.0	*	1.5	8.5	16.5	13.0			
1-butene	*	*	*	*	*	*	*	*	*	*			
i-butene	1.0	0.5	1.0	0.5	1.0	*	1.5	*	1.0	1.0			
t-2-butene	*	*	*	*	*	*	*	*	*	*			
propyne	*	*	*	*	*	*	*	*	*	*			
c-2-butene	*	*	*	*	*	*	*	*	*	*			
i-pentane	2.0	3.5	9.0	13.5	20.0	*	1.0	8.5	14.0	11.0			
n-pentane	1.0	1.5	3.5	5.5	7.5	*	*	4.0	6.0	5.0			
cyclopentane	*	*	*	1.0	1.5	*	*	*	1.0	0.5			
1-pentene	*	*	*	*	*	*	*	*	*	*			
M-hexane	-	1.0	-	-	-	-	-	2.0	3.5	2.5			
3-m-pentane	-	-	-	-	-	-	-	1.5	2.5	1.5			
n-hexane	-	-	-	-	-	-	-	2.0	3.0	2.5			
Σolefins	2.0	2.0	5.0	5.0	8.0	0	5.0	4.5	5.5	3.5			
Σparaffins	12.0	17.5	57.5	89.0	130.5	7.0	6.5	45.5	74.5	57.0			
Total $\mu g/m^3$	14.0	21.0	64.5	95.5	140.5	7.0	11.5	52.5	82.5	61.5			
Total ppm C	0.02	0.03	0.10	0.15	0.22	0.01	0.02	0.08	0.13	0.09			
CH_4 (ppm)	1.7	1.6	1.7	1.9	2.0	-	-	1.7	1.7	-			
CO (ppm)	0.4	0.5	0.6	0.6	0.7	-	-	0.7	0.6	-			
$CFCl_3$ (ppt)	-	-	-	-	-	-	-	-	-	-			
CCl_4 (ppt)	-	-	-	-	-	-	-	-	-	-			

* < 0.5 $\mu g/m^3$ - missing data

TABLE C3. LIGHT HYDROCARBON CONCENTRATIONS IN AIRCRAFT COLLECTED SAMPLES ON SEPTEMBER 10, 1975

	Concentration ($\mu g/m^3$)												
	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10	A-11	A-12	A-13
ethane	11.0	11.0	9.0	10.0	11.0	8.0	6.0	3.5	3.5	5.5	5.0	6.0	6.5
ethylene	4.0	4.5	4.0	4.0	5.5	3.0	2.5	*	1.0	2.0	1.5	1.5	1.5
acetylene	2.0	2.0	1.5	1.5	2.0	2.0	1.0	*	*	1.0	1.0	2.0	1.5
propane	15.0	10.5	11.0	12.5	24.0	14.5	4.0	1.5	2.0	3.0	5.0	3.0	5.5
propene	2.5	2.5	2.0	2.5	3.5	2.0	1.0	*	*	0.5	1.0	*	*
i-butane	8.5	9.0	6.5	8.0	11.0	6.0	3.0	*	1.0	1.5	3.0	2.0	3.0
n-butane	18.5	18.5	14.5	15.5	18.0	13.5	6.0	*	2.5	3.5	6.0	4.0	6.0
1-butene	1.0	1.0	1.0	1.0	1.5	*	*	*	-	*	*	*	*
i-butene	1.5	1.5	1.5	1.5	1.5	1.5	1.0	*	-	0.5	1.0	1.0	0.5
t-2-butene	*	0.5	*	0.5	*	*	*	*	-	*	*	*	*
propyne	*	*	*	*	*	*	*	*	-	*	*	*	*
c-2-butene	*	*	*	*	*	*	*	*	-	*	*	*	*
i-pentane	17.5	18.5	16.0	13.5	17.5	19.5	9.0	*	2.0	4.5	7.5	4.5	6.0
n-pentane	7.0	8.0	5.5	7.0	7.0	7.5	3.5	*	1.0	2.0	5.5	2.0	3.0
cyclopentane	1.0	1.0	1.0	*	1.0	1.0	1.0	*	-	*	1.0	*	*
1-pentene	1.0	1.0	0.5	1.0	1.5	*	*	*	-	*	*	*	*
M-hexane	3.5	4.0	3.0	3.0	4.0	4.0	2.0	*	-	1.0	2.0	1.0	1.5
3-m-pentane	2.5	2.5	2.0	2.0	4.0	3.0	2.0	*	-	1.0	1.5	1.5	1.0
n-hexane	-	4.0	2.5	3.0	4.0	-	2.0	*	-	1.0	2.0	1.0	1.5
								*	-				
Σolefins	10.0	11.0	8.5	10.5	13.5	6.5	4.5	0	1.0	3.0	3.5	2.5	2.0
Σparaffins	84.5	87.0	71.0	74.5	101.5	77.0	38.5	5.0	12.0	23.0	38.5	25.0	34.0
Total $\mu g/m^3$	96.5	100.0	81.0	86.5	117.0	85.5	44.0	5.0	13.0	27.0	43.0	29.5	37.5
Total ppm C	0.15	0.15	0.12	0.13	0.18	0.13	0.07	0.01	0.02	0.04	0.07	0.05	0.06
CH_4 (ppm)	1.7	1.7	1.7	1.7	1.8	1.7	1.7	-	1.6	1.7	-	-	-
CO (ppm)	0.6	0.7	0.6	0.6	0.6	0.6	0.6	-	0.4	0.6	-	-	-
$CFCl_3$ (ppt)	-	-	-	-	-	-	-	-	-	-	-	-	-
CCl_4 (ppt)	-	-	-	-	-	-	-	-	-	-	-	-	-

* < 0.5 $\mu g/m^3$ - missing data

TABLE C4. LIGHT HYDROCARBON CONCENTRATIONS IN AIRCRAFT COLLECTED SAMPLES ON SEPTEMBER 11, 1975

	Concentration ($\mu g/m^3$)												
	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10	A-11	A-12	A-13
ethane	7.5	10.5	4.5	5.0	5.5	12.0	6.0	7.5	7.0	5.0			
ethylene	1.5	3.5	*	2.5	1.5	4.5	2.5	2.5	2.0	1.5			
acetylen	1.0	3.0	*	1.0	1.0	1.5	2.0	1.5	1.0	1.0			
propane	8.0	6.5	2.0	3.0	4.5	8.0	4.0	10.0	10.5	4.5			
propene	*	1.0	*	1.0	1.0	3.5	1.0	2.0	1.5	1.5			
i-butane	4.5	5.5	1.0	1.5	2.5	9.0	3.0	6.5	6.0	3.0			
n-butane	6.5	13.5	1.5	3.0	3.5	16.5	4.5	9.5	6.5	4.5			
1-butene	*	*	*	*	*	1.5	*	*	*	*			
i-butene	*	*	*	0.5	0.5	2.0	*	1.0	1.0	1.0			
t-2-butene	*	*	*	*	*	1.5	*	*	*	*			
propyne	*	*	*	*	*	*	*	*	*	*			
c-2-butene	*	*	*	*	*	*	*	*	*	*			
i-pentane	9.0	13.0	1.5	4.0	4.0	15.0	5.5	12.0	8.5	6.0			
n-pentane	4.5	7.0	*	1.5	1.5	11.0	2.5	5.0	3.5	2.5			
cyclopentane	-	1.0	*	*	*	0.5	*	*	*	*			
1-pentene	*	*	*	*	*	*	*	*	*	*			
M-hexane	2.0	3.5	*	1.0	1.0	4.0	1.5	3.0	2.0	1.5			
3-m-pentane	1.0	2.5	*	-	-	2.5	1.0	2.0	1.5	1.0			
n-hexane	1,0	3.5	*	-	-	4.5	1.5	3.0	1.0	1.5			
Σolefins	1.5	4.5	0	4.0	3.0	13.0	3.5	5.5	4.5	4.0			
Σparaffins	44.5	67.5	10.5	19.0	22.5	83.0	29.5	58.5	46.5	29.5			
Total $\mu g/m^3$	47.0	75.0	10.5	24.0	26.5	97.5	35.0	65.5	52.0	34,5			
Total ppm C	0.07	0.12	0.02	0.04	0.04	0.15	0.05	0.10	0.08	0.05			
CH_4 (ppm)	-	-	-	1.6	1.6	1.6	1.6	1.6	1.7	1.6			
CO (ppm)	-	-	-	0.5	0.7	0.7	0.5	0.5	0.6	0.6			
$CFCl_3$ (ppt)	167	297	179	-	-	188	181	-	-	-			
CCl_4 (ppt)	183	144	135	-	-	125	135	-	-	-			

* < 0.5 $\mu g/m^3$ - missing data

TABLE C5. LIGHT HYDROCARBON CONCENTRATIONS IN AIRCRAFT COLLECTED SAMPLES ON SEPTEMBER 12, 1975

	Concentration (μg/m^3)												
	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10	A-11	A-12	A-13
ethane	3.5	11.0	4.5	7.5									
ethylene	*	3.0	1.5	4.0									
acetylene	*	3.5	0.5	1.5									
propane	2.5	6.5	2.5	4.5									
propene	*	0.5	*	*									
i-butane	*	5.0	1.0	1.5									
n-butane	0.5	11.5	2.0	3.5									
1-butene	*	*	-	*									
i-butene	*	*	-	0.5									
t-2-butene	*	*	-	*									
propyne	*	*	-	*									
c-2-butene	*	*	-	*									
i-pentane	*	10.5	2.0	4.5									
n-pentane	*	4.5	1.0	2.0									
cyclopentane	*	0.5	-	*									
1-pentene	*	1.0	-	*									
i-hexane	*	2.5	-	1.5									
3-m-pentane	*	1.5	-	1.0									
n-hexane	*	2.5	-	1.5									
Σolefins	0	4.5	1.5	4.5									
Σparaffins	6.5	56.0	13.0	27.0									
Total μg/m^3	6.5	64.0	15.0	33.5									
Total ppm C	0.01	0.10	0.02	0.05									
CH_4 (ppm)	-	-	1.6	1.7									
CO (ppm)	-	-	0.6	0.7									
$CFCl_3$ (ppt)	273	154	-	-									
CCl_4 (ppt)	481	116	-	-									

* < 0.5 μg/m^3

- missing data

TABLE C6. LIGHT HYDROCARBON CONCENTRATIONS IN AIRCRAFT COLLECTED SAMPLES ON SEPTEMBER 13, 1975

	Concentration ($\mu g/m^3$)												
	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10	A-11	A-12	A-13
ethane	3.5	12.5	6.0	8.0	6.0	12.5	13.5	5.5	5.5	8.0	8.5	10.5	
ethylene	*	4.0	2.5	3.5	2.0	3.5	2.5	1.5	1.0	1.5	2.5	2.0	
acetylene	*	2.0	2.0	1.0	2.0	1.5	1.5	1.0	1.0	1.5	1.0	1.0	
propane	1.5	12.5	7.0	5.5	4.0	15.5	33.0	11.0	4.0	7.5	8.0	10.5	
propene	*	4.0	1.0	1.0	1.0	2.0	1.5	1.0	*	1.0	1.0	1.5	
i-butane	*	10.5	3.0	5.0	5.0	13.0	11.5	2.5	4.0	5.0	5.5	10.0	
n-butane	*	27.5	5.5	7.0	7.5	15.0	14.0	8.5	6.0	6.0	6.0	10.5	
1-butene	*	1.5	*	*	*	*	*	*	-	-	*	*	
i-butene	*	2.5	1.0	0.5	1.0	1.0	1.0	1.0	-	-	*	1.0	
t-2-butene	*	1.5	*	*	*	0.5	*	*	-	-	*	*	
propyne	*	*	*	*	*	*	*	*	-	-	*	*	
c-2-butene	*	2.0	*	*	*	*	*	*	-	-	*	*	
i-pentane	*	26.0	6.0	8.0	8.5	16.5	14.0	10.0	5.0	7.5	6.0	11.5	
n-pentane	*	15.0	3.5	4.0	3.0	5.5	4.5	3.0	2.5	3.0	2.0	4.0	
cyclopentane	*	1.5	*	*	*	1.0	1.0	1.0	-	-	*	*	
1-pentene	*	1.0	*	*	*	1.0	*	*	-	-	*	*	
i-hexane	*	7.0	1.5	1.5	1.5	3.5	-	2.0	-	-	1.0	2.0	
3-m-pentane	*	4.5	1.0	-	1.0	2.5	-	1.0	-	-	1.0	1.5	
n-hexane	*	8.0	1.0	-	2.5	1.5	-	1.5	-	-	1.0	1.5	
Σolefins	0	16.5	4.5	5.0	4.0	8.0	5.0	3.5	1.0	2.5	3.5	4.5	
Σparaffins	5.0	125.0	54.5	39.0	39.0	86.5	91.5	47.0	27.0	37.0	39.0	62.0	
Total $\mu g/m^3$	5.0	143.5	41.0	45.0	45.0	96.0	98.0	51.5	29.0	41.0	43.5	67.5	
Total ppm C	0.01	0.22	0.06	0.07	0.07	0.15	0.15	0.08	0.04	0.06	0.07	0.10	
CH_4 (ppm)	-	1.8	-	1.7	1.7	1.8	1.8	1.6	-	1.7	-	-	
CO (ppm)	-	0.9	-	0.7	0.6	0.5	0.7	0.7	-	0.5	-	-	
$CFCl_3$ (ppt)	118	-	-	-	-	-	-	-	144	-	141	141	
CCl_4 (ppt)	116	-	-	-	-	-	-	-	116	-	116	116	

* < 0.5 $\mu g/m^3$ — - missing data

TABLE C7. LIGHT HYDROCARBON CONCENTRATIONS IN AIRCRAFT COLLECTED SAMPLES ON SEPTEMBER 14,1975

	Concentration ($\mu g/m^3$)												
	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10	A-11	A-12	A-13
ethane	3.5	4.0	3.5	5.5	6.0	4.0	6.5	8.5	5.0	6.0	4.5		
ethylene	*	*	*	1.0	1.0	1.5	1.5	2.5	0.5	1.0	1.0		
acetylene	*	*	*	1.0	1.0	*	1.0	3.0	0.5	1.5	*		
propane	1.5	2.0	1.5	4.5	7.5	2.0	5.5	3.0	3.0	2.0	2.5		
propene	*	*	*	1.0	*	*	1.0	*	*	*	*		
i-butane	*	*	*	3.0	4.0	0.5	6.5	2.0	3.0	1.0	1.0		
n-butane	*	1.0	*	5.0	6.0	1.5	15.0	4.0	8.0	2.5	2.0		
1-butene	*	*	*	*	*	*	*	*	*	*	*		
i-butene	*	*	*	*	*	1.0	1.0	1.0	1.0	*	*		
t-2-butene	*	*	*	*	*	*	*	*	*	*	*		
propyne	*	*	*	*	*	*	*	*	*	*	*		
c-2-butene	*	*	*	*	*	*	*	*	*	*	*		
i-pentane	*	1.0	*	5.0	7.5	2.5	9.0	5.5	5.5	3.5	2.5		
n-pentane	*	1.0	*	2.5	3.0	1.0	5.5	2.0	3.5	1.5	1.5		
cyclopentane	*	*	*	*	*	*	*	*	*	*	*		
1-pentene	*	*	*	*	*	*	*	*	*	*	*		
i-hexane	*	*	*	1.5	-	-	2.0	1.5	1.5	1.0	*		
3-m-pentane	*	*	*	1.0	-	-	1.5	1.0	*		*		
n-hexane	*	*	*	1.5	-	-	2.0	-	1.0	-	*		
Σolefins	0	0	0	2.0	1.0	2.5	3.5	3.5	1.5	1.0	1.0		
Σparaffins	5.0	9.0	5.0	29.5	34.0	11.5	53.5	27.5	30.5	17.5	14.0		
Total $\mu g/m^3$	5.0	9.0	5.0	32.5	36.0	14.0	58.0	34.0	32.5	20.0	15.0		
Total ppm C	0.01	0.01	0.01	0.05	0.06	0.02	0.09	0.05	0.05	0.03	0.02		
CH_4 (ppm)	-	1.6	1.7	1.6	1.6	1.6	-	1.7	1.7	1.7	1.8		
CO (ppm)	-	0.5	0.4	0.5	0.5	0.6	-	0.7	0.6	0.6	0.5		
$CFCl_3$ (ppt)	121	134	128	140	150	-	151	209	144	196	141		
CCl_4 (ppt)	124	116	124	124	132	-	124	124	124	149	125		

* < 0.5 $\mu g/m^3$ - missing data

TABLE C8. LIGHT HYDROCARBON CONCENTRATIONS IN AIRCRAFT COLLECTED SAMPLES ON SEPTEMBER 15, 1975

	Concentration (μg/m^3)												
	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10	A-11	A-12	A-13
ethane	3.0	6.5	3.5	4.0	5.5	7.0	11.5	7.0	5.5	3.5			
ethylene	*	1.0	*	0.5	1.0	3.0	3.5	2.0	1.0	*			
acetylene	*	0.5	*	0.5	1.0	2.5	2.5	1.5	2.0	*			
propane	1.0	5.0	1.5	1.5	5.0	7.5	7.0	3.2	3.0	2.0			
propene	*	*	*	*	*	1.0	*	*	*	*			
i-butane	*	4.0	*	1.5	2.0	9.5	6.0	2.0	3.0	*			
n-butane	*	5.5	*	2.5	2.5	21.0	13.5	3.5	4.5	1.0			
1-butene	*	*	*	-	-	-	*	*	*	*			
i-butene	*	*	*	-	-	-	*	*	*	*			
t-2-butene	*	*	*	-	-	-	*	*	*	*			
propyne	*	*	*	-	-	-	*	*	*	*			
c-2-butene	*	*	*	-	-	-	*	*	*	*			
i-pentane	*	5.0	*	3.0	3.0	15.0	12.0	3.5	4.5	1.0			
n-pentane	*	2.5	*	0.5	1.5	7.5	6.0	1.5	1.5	*			
cyclopentane	*	*	*	-	-	-	-	*	*	*			
1-pentene	*	*	*	-	-	-	-	*	*	*			
i-hexane	*	1.5	*	-	-	-	4.0	-	-	*			
3-m-pentane	*	1.0	*	-	-	-	2.5	-	-	*			
n-hexane	*	1.5	*	-	-	-	3.5	-	-	*			
Σolefins	0	1.0	0	0.5	1.0	4.0	3.5	2.0	1.0	0			
Σparaffins	4.0	32.5	5.0	13.0	19.5	67.5	65.0	21.0	22.0	7.5			
Total μg/m^3	4.0	34.0	5.0	14.0	21.5	74.0	72.0	24.5	25.0	7.5			
Total ppm C	0.01	0.05	0.01	0.02	0.03	0.11	0.11	0.04	0.04	0.01			
CH_4 (ppm)	-	1.6	1.5	1.5	1.6	1.7	-	1.6	1.7	-			
CO (ppm)	-	0.4	0.2	0.4	0.2	0.7	-	0.5	0.7	-			
$CFCl_3$ (ppt)	121	147	128	144	147	179	251	148	176	136			
CCl_4 (ppt)	125	133	125	125	125	124	165	116	165	124			

* < 0.5 μg/m^3

- missing data

TABLE C9. LIGHT HYDROCARBON CONCENTRATIONS IN AIRCRAFT COLLECTED SAMPLES ON SEPTEMBER 16, 1975

	Concentration ($\mu g/m^3$)												
	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10	A-11	A-12	A-1
ethane	3.0	9.0	7.5	11.0	7.0	13.0	4.0	5.5	6.0	4.5			
ethylene	*	3.0	2.5	5.5	3.0	5.0	1.0	1.5	1.5	0.5			
acetylene	*	2.0	2.0	4.5	2.0	3.0	1.5	1.0	1.5	0.5			
propane	1.5	7.5	5.5	7.0	6.5	19.0	3.0	2.5	3.5	2.5			
propene	*	1.5	1.0	1.5	1.0	2.5	*	*	*	*			
i-butane	*	4.0	2.5	4.5	4.0	9.5	1.5	1.0	1.5	1.0			
n-butane	*	7.0	4.5	7.0	5.5	16.0	3.0	2.0	2.5	2.0			
1-butene	*	*	*	*	*	*	*	*	*	*			
i-butene	*	1.0	*	1.0	1.0	1.0	0.5	*	*	0.5			
t-2-butene	*	*	*	*	*	*	*	*	*	*			
propyne	*	*	*	*	*	*	*	*	*	*			
c-2-butene	*	*	*	*	*	*	*	*	*	*			
i-pentane	*	8.5	5.5	10.0	8.5	18.0	4.5	3.0	3.0	1.5			
n-pentane	*	4.0	2.0	4.0	3.0	6.5	2.5	1.0	1.0	*			
cyclopentane	*	*	*	*	*	*	*	*	*	*			
1-pentene	*	*	*	*	*	1.0	*	*	*	*			
i-hexane	*	2.5	1.5	3.5	2.5	4.5	1.0	0.5	1.0	*			
3-m-pentane	*	1.5	1.0	2.0	1.5	3.0	1.0	*	*	*			
n-hexane	*	3.0	1.5	3.0	2.0	4.0	1.0	*	*	*			
Σolefins	0	5.5	3.5	8.0	5.0	9.5	1.5	1.5	1.5	1.0			
Σparaffins	4.5	47.0	31.5	52.0	40.5	93.5	21.5	15.5	18.5	11.5			
Total $\mu g/m^3$	4.5	54.5	37.0	64.5	47.5	106.0	24.5	18.0	21.5	13.0			
Total ppm C	0.01	0.08	0.06	0.10	0.07	0.16	0.04	0.03	0.03	0.02			
CH_4 (ppm)	1.3	1.7	1.5	1.6	1.6	1.7	1.5	1.4	1.2	-			
CO (ppm)	0.2	0.8	0.6	1.0	0.7	0.9	0.6	0.4	0.4	-			
$CFCl_3$ (ppt)	124	-	-	-	-	-	-	-	174	140			
CCl_4 (ppt)	116	-	-	-	-	-	-	-	132	124			

* < 0.5 $\mu g/m^3$ - missing data

TABLE C10. LIGHT HYDROCARBON CONCENTRATIONS IN SAMPLES COLLECTED AT GROUND LEVEL ON SEPTEMBER 10, 1975

	Concentration ($\mu g/m^3$)						
	G-1	G-2	G-3	G-4	G-5	G-6	G-7
ethane	11.5	10.0	10.5				
ethylene	3.5	5.5	7.5				
acetylene	2.0	6.5	6.0				
propane	10.0	5.5	3.5				
propene	2.5	1.5	2.0				
i-butane	9.0	4.5	2.5				
n-butane	21.0	13.5	7.0				
1-butene	1.0	*	*				
i-butene	2.0	1.0	1.5				
t-2-butene	1.0	*	1.0				
propyne	*	*	*				
c-2-butene	*	*	*				
i-pentane	18.5	14.0	12.5				
n-pentane	10.0	6.5	4.5				
cyclopentane	1.0	1.5	1.5				
1-pentene	1.0	*	*				
i-hexane	5.0	4.0	4.0				
3-m-pentane	3.0	3.0	4.0				
n-hexane	4.5	3.5	4.5				
Σolefins	11.0	8.0	12.0				
Σparaffins	93.5	66.0	54.0				
Total $\mu g/m^3$	106.5	80.5	72.5				
Total ppm C	0.16	0.12	0.11				
CH_4 (ppm)	-	-	-				
CO (ppm)	-	-	-				
$CFCl_3$ (ppt)	-	251	308				
CCl_4 (ppt)	-	115	183				

* < 0.5 $\mu g/m^3$

- missing data

TABLE C11. LIGHT HYDROCARBON CONCENTRATIONS IN SAMPLES COLLECTED AT GROUND LEVEL ON SEPTEMBER 11, 1975

	Concentration ($\mu g/m^3$)						
	G-1	G-2	G-3	G-4	G-5	G-6	G-7
ethane	9.5						
ethylene	2.5						
acetylene	1.5						
propane	9.0						
propene	1.5						
i-butane	6.0						
n-butane	12.5						
1-butene	*						
i-butene	1.0						
t-2-butene	*						
propyne	*						
c-2-butene	*						
i-pentane	12.0						
n-pentane	7.0						
cyclopentane	*						
1-pentene	*						
i-hexane	3.0						
3-m-pentane	2.0						
n-hexane	2.5						
Σolefins	5.0						
Σparaffins	65.5						
Total $\mu g/m^3$	72.0						
Total ppm C	0.11						
CH_4 (ppm)	-						
CO (ppm)	-						
$CFCl_3$ (ppt)	186						
CCl_4 (ppt)	144						

* < 0.5 $\mu g/m^3$ - missing data

TABLE C12. LIGHT HYDROCARBON CONCENTRATIONS IN SAMPLES COLLECTED AT GROUND LEVEL ON SEPTEMBER 12, 1975

	Concentration ($\mu g/m^3$)						
	G-1	G-2	G-3	G-4	G-5	G-6	G-7
ethane	6.0	5.5					
ethylene	2.0	2.0					
acetylene	1.5	1.5					
propane	5.0	3.0					
propene	1.0	0.5					
i-butane	3.5	1.5					
n-butane	6.0	3.0					
1-butene	*	*					
i-butene	1.0	*					
t-2-butene	*	*					
propyne	*	*					
c-2-butene	*	*					
i-pentane	5.5	4.0					
n-pentane	2.5	1.5					
cyclopentane	*	*					
1-pentene	*	*					
i-hexane	1.5	1.0					
3-m-pentane	1.0	1.0					
n-hexane	1.5	1.0					
Σolefins	4.0	2.5					
Σparaffins	31.5	21.5					
Total $\mu g/m^3$	37.0	25.5					
Total ppm C	0.06	0.04					
CH_4 (ppm)	1.6	-					
CO (ppm)	0.6	-					
$CFCl_3$ (ppt)	-	-					
CCl_4 (ppt)	-	-					

* < 0.5 $\mu g/m^3$ - missing data

TABLE C13. LIGHT HYDROCARBON CONCENTRATIONS IN SAMPLES COLLECTED AT GROUND LEVEL ON SEPTEMBER 13,1975

	Concentration ($\mu g/m^3$)						
	G-1	G-2	G-3	G-4	G-5	G-6	G-7
ethane	10.5	4.5	4.0				
ethylene	2.5	1.0	*				
acetylene	3.0	1.0	*				
propane	8.0	2.5	1.5				
propene	1.5	*	*				
i-butane	16.5	1.5	*				
n-butane	28.0	3.5	1.0				
1-butene	0.5	*	*				
i-butene	1.0	*	*				
t-2-butene	*	*	*				
propyne	*	*	*				
c-2-butene	*	*	*				
i-pentane	26.0	5.0	1.0				
n-pentane	12.0	2.0	*				
cyclopentane	1.5	*	*				
1-pentene	*	*	*				
i-hexane	*	*	*				
3-m-pentane	*	*	*				
n-hexane	*	*	*				
Σolefins	5.5	1.0	0				
Σparaffins	102.5	19.0	7.5				
Total $\mu g/m^3$	111.0	21.0	7.5				
Total ppm C	0.17	0.03	0.01				
CH_4 (ppm)	-	-	-				
CO (ppm)	-	-	-				
$CFCl_3$ (ppt)	221	157	125				
CCl_4 (ppt)	116	116	116				

* < 0.5 $\mu g/m^3$

- missing data

TABLE C14. LIGHT HYDROCARBON CONCENTRATIONS IN SAMPLES COLLECTED AT GROUND LEVEL ON SEMPTEMBER 14, 1975

	Concentration ($\mu g/m^3$)						
	G-1	G-2	G-3	G-4	G-5	G-6	G-7
ethane	18.5	5.0	7.0				
ethylene	2.0	1.5	1.5				
acetylene	0.5	1.0	1.5				
propane	10.0	3.5	5.0				
propene	1.0	1.0	0.5				
i-butane	6.5	3.0	4.0				
n-butane	18.5	5.0	4.5				
1-butene	*	*	*				
i-butene	0.5	*	*				
t-2-butene	*	*	*				
propyne	*	*	*				
c-2-butene	*	*	*				
i-pentane	43.0	4.5	4.5				
n-pentane	9.5	3.5	2.5				
cyclopentane	*	*	1.0				
1-pentene	2.5	*	*				
i-hexane	8.5	*	*				
3-m-pentane	4.5	*	*				
n-hexane	*	*	*				
Σolefins	6.0	2.5	2.0				
Σparaffins	119.0	24.0	28.5				
Total $\mu g/m^3$	125.5	28.0	32.0				
Total ppm C	0.19	0.04	0.05				
CH_4 (ppm)	1.6	1.7	-				
CO (ppm)	0.6	0.6	-				
$CFCl_3$ (ppt)	-	-	-				
CCl_4 (ppt)	-	-	-				

* < 0.5 $\mu g/m^3$

- missing data

TABLE C15. LIGHT HYDROCARBON CONCENTRATIONS IN SAMPLES COLLECTED AT GROUND LEVEL ON SEPTEMBER 15, 1975

	Concentration ($\mu g/m^3$)						
	G-1	G-2	G-3	G-4	G-5	G-6	G-7
ethane	5.0						
ethylene	*						
acetylene	1.0						
propane	4.0						
propene	1.5						
i-butane	7.5						
n-butane	30.5						
1-butene	1.0						
i-butene	1.0						
t-2-butene	*						
propyne	*						
c-2-butene	*						
i-pentane	34.5						
n-pentane	7.5						
cyclopentane	3.0						
1-pentene	2.0						
i-hexane	5.0						
3-m-pentane	3.0						
n-hexane	3.5						
Σolefins	5.5						
Σparaffins	103.5						
Total $\mu g/m^3$	110.0						
Total ppm C	0.17						
CH_4 (ppm)	-						
CO (ppm)	-						
$CFCl_3$ (ppt)	-						
CCl_4 (ppt)	-						

* < 0.5 $\mu g/m^3$

- missing data

TABLE C16. LIGHT HYDROCARBON CONCENTRATIONS IN SAMPLES COLLECTED AT GROUND LEVEL ON SEPTEMBER 16, 1975

	Concentration ($\mu g/m^3$)						
	G-1	G-2	G-3	G-4	G-5	G-6	G-7
ethane	12.5	7.5					
ethylene	3.5	2.5					
acetylene	2.5	2.0					
propane	11.0	6.5					
propene	2.0	1.5					
i-butane	6.5	10.0					
n-butane	10.5	18.0					
1-butene	*	0.5					
i-butene	1.5	1.0					
t-2-butene	*	*					
propyne	*	*					
c-2-butene	*	*					
i-pentane	8.0	18.5					
n-pentane	3.5	7.5					
cyclopentane	*	1.0					
1-pentene	1.0	1.0					
i-hexane	2.0	8.5					
3-m-pentane	1.5	6.0					
n-hexane	2.0	9.5					
Σolefins	8.0	6.5					
Σparaffins	58.0	93.0					
Total $\mu g/m^3$	68.5	101.5					
Total ppm C	0.11	0.16					
CH_4 (ppm)	-	-					
CO (ppm)	-	-					
$CFCl_3$ (ppt)	-	-					
CCl_4 (ppt)	-	-					

* < 0.5 $\mu g/m^3$

- missing data

TABLE C17. LIGHT HYDROCARBON CONCENTRATIONS IN SAMPLES COLLECTED AT GROUND LEVEL ON SEPTEMBER 17, 1975

	Concentration ($\mu g/m^3$)						
	G-1	G-2	G-3	G-4	G-5	G-6	G-7
ethane	8.0	9.5					
ethylene	3.5	3.0					
acetylene	2.0	2.0					
propane	13.0	7.0					
propene	2.0	1.5					
i-butane	15.0	5.0					
n-butane	31.5	8.5					
1-butene	2.5	1.0					
i-butene	2.5	*					
t-2-butene	4.0	*					
propyne	*	*					
c-2-butene	*	*					
i-pentane	154.0	8.0					
n-pentane	28.5	3.0					
cyclopentane	*	*					
1-pentene	*	8.5					
i-hexane	33.0	2.0					
3-m-pentane	20.0	1.5					
n-hexane	10.0	2.5					
Σolefins	14.5	14.0					
Σparaffins	313.0	47.0					
Total $\mu g/m^3$	329.5	63.0					
Total ppm C	0.50	0.10					
CH_4 (ppm)	-	-					
CO (ppm)	-	-					
$CFCl_3$ (ppt)	-	-					
CCl_4 (ppt)	-	-					

* < 0.5 $\mu g/m^3$ - missing data

TABLE C18. LIGHT HYDROCARBON CONCENTRATIONS IN SAMPLES COLLECTED AT GROUND LEVEL ON SEPTEMBER 18, 1975

	Concentration (μg/m^3)						
	G-1	G-2	G-3	G-4	G-5	G-6	G-7
ethane	6.5	4.5					
ethylene	1.5	1.5					
acetylene	*	7.0					
propane	18.0	3.5					
propene	1.0	*					
i-butane	16.5	1.0					
n-butane	43.0	2.0					
1-butene	1.5	*					
i-butene	2.0	1.0					
t-2-butene	2.5	*					
propyne	*	*					
c-2-butene	*	*					
i-pentane	231.5	4.0					
n-pentane	31.5	1.0					
cyclopentane	5.0	*					
1-pentene	*	*					
i-hexane	42.0	1.0					
3-m-pentane	23.0	*					
n-hexane	20.5	*					
Σolefins	8.5	2.5					
Σparaffins	437.5	17.0					
Total μg/m^3	446.0	26.5					
Total ppm C	0.68	0.04					
CH_4 (ppm)	-	-					
CO (ppm)	-	-					
$CFCl_3$ (ppt)	-	-					
CCl_4 (ppt)	-	-					

* < 0.5 μg/m^3

- missing data

TABLE C19. LIGHT HYDROCARBON CONCENTRATIONS IN SAMPLES COLLECTED AT GROUND LEVEL ON SEPTEMBER 19, 1975

	Concentration ($\mu g/m^3$)						
	G-1	G-2	G-3	G-4	G-5	G-6	G-7
ethane	3.5	4.0	6.0	8.5	3.0	10.0	10.5
ethylene	1.0	1.0	1.0	1.5	*	25.0	25.5
acetylene	*	*	*	1.0	*	28.5	16.5
propane	3.5	1.0	36.0	12.5	6.0	7.0	5.0
propene	*	*	0.5	1.0	*	13.0	9.0
i-butane	8.0	0.5	31.0	9.0	16.5	18.0	22.0
n-butane	36.0	1.5	44.0	12.5	105.0	49.5	50.0
1-butene	*	*	1.0	1.0	*	3.5	2.5
i-butene	1.5	0.5	2.0	1.0	1.0	6.0	7.0
t-2-butene	*	*	2.5	2.0	1.0	8.5	8.5
propyne	*	*	*	*	*	*	*
c-2-butene	*	*	*	*	*	*	*
i-pentane	43.5	1.5	67.5	45.0	115.5	117.0	129.5
n-pentane	12.5	*	18.5	9.0	32.0	36.5	43.0
cyclopentane	1.5	*	2.5	1.5	4.0	3.5	18.0
1-pentene	*	*	6.0	6.0	*	*	*
i-hexane	8.0	*	18.5	10.0	21.0	40.5	48.0
3-m-pentane	4.5	*	11.5	6.0	12.5	24.5	29.5
n-hexane	5.0	*	10.0	3.0	12.0	29.0	3.0
Σolefins	2.5	1.5	13.0	12.5	2.0	56.0	52.5
Σparaffins	126.0	8.5	245.5	117.0	327.5	335.5	358.5
Total $\mu g/m^3$	128.5	10.0	258.5	130.5	329.5	420.0	427.5
Total ppm C	0.20	0.02	0.40	0.20	0.50	0.64	0.65
CH_4 (ppm)	-	-	-	-	-	1.4	1.4
CO (ppm)	-	-	-	-	-	3.0	2.8
$CFCl_3$ (ppt)	-	-	-	-	-	-	-
CCl_4 (ppt)	-	-	-	-	-	-	-

* < 0.5 $\mu g/m^3$ - missing data

TABLE C20. LIGHT HYDROCARBON CONCENTRATIONS IN SAMPLES COLLECTED AT GROUND LEVEL ON SEPTEMBER 20, 1975

	Concentration ($\mu g/m^3$)						
	G-1	G-2	G-3	G-4	G-5	G-6	G-7
ethane	10.0	13.0					
ethylene	2.5	3.0					
acetylene	2.5	2.5					
propane	4.5	42.0					
propene	1.0	1.5					
i-butane	2.0	29.0					
n-butane	4.0	53.5					
1-butene	*	1.0					
i-butene	1.5	1.5					
t-2-butene	*	*					
propyne	*	*					
c-2-butene	*	*					
i-pentane	6.0	100.0					
n-pentane	2.5	34.0					
cyclopentane	*	*					
1-pentene	*	*					
i-hexane	2.0	23.5					
3-m-pentane	1.5	14.5					
n-hexane	1.5	14.0					
Σolefins	5.0	7.0					
Σparaffins	34.0	323.5					
Total $\mu g/m^3$	41.5	333.0					
Total ppm C	0.06	0.51					
CH_4 (ppm)	-	-					
CO (ppm)	-	-					
$CFCl_3$ (ppt)	-	-					
CCl_4 (ppt)	-	-					

* < 0.5 $\mu g/m^3$

- missing data

TABLE C21. LOCATION OF AIRCRAFT COLLECTED HYDROCARBON SAMPLES ON SEPTEMBER 8, 1975

A-1	Over Washington State University trailer site at 7,000 ft. MSL*
A-2	2 miles downwind across the Exxon plume at 1,000 ft. MSL.
A-3	5 miles downwind across the Exxon plume at 1,000 ft. MSL.
A-4	2 miles upwind of the Exxon refinery at 1,500 ft. MSL.
A-5	Over Washington State University trailer at 7,000 ft. MSL.
A-6	20 miles downwind of the Exxon refinery in suspected area of plume drift at 500 ft. MSL.
A-7	
A-8	
A-9	
A-10	
A-11	
A-12	
A-13	

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* above mean sea level

TABLE C22. LOCATION OF AIRCRAFT COLLECTED HYDROCARBON SAMPLES ON SEPTEMBER 9, 1975

A-1	**3 miles downwind across the Exxon plume at 1,600 ft. MSL.**
A-2	**3 miles downwind across the Exxon plume at 1,100 ft. MSL.**
A-3	**3 miles downwind across the Exxon plume at 900 ft. MSL.**
A-4	**3 miles downwind across the Exxon plume at 650 ft. MSL.**
A-5	**3 miles downwind across the Exxon plume at 300 ft. MSL.**
A-6	**Over the Washington State University trailer at 6,000 ft. MSL.**
A-7	**Over San Pablo Bay at 1,000 ft. MSL.**
A-8	**40 miles downwind of the Exxon refinery, NE of Tracy at 700 ft. MSL.**
A-9	**32 miles downwind of the Exxon refinery, NE of Brentwood at 600 ft. MSL.**
A-10	**14 miles downwind of the Exxon refinery, West of Pittsburgh at 600 ft. MSL.**
A-11	
A-12	
A-13	

TABLE C23. LOCATION OF AIRCRAFT COLLECTED HYDROCARBON SAMPLES ON SEPTEMBER 10, 1975

A-1	Between Benicia and the Exxon refinery at 800 ft. MSL.
A-2	5 miles downwind across the Exxon plume at 600 ft. MSL.
A-3	5 miles downwind across the Exxon plume at 800 ft. MSL.
A-4	5 miles downwind across the Exxon plume at 1,000 ft. MSL.
A-5	8 miles downwind across the Exxon plume at 500 ft. MSL.
A-6	8 miles downwind across the Exxon plume at 800 ft. MSL
A-7	8 miles downwind across the Exxon plume at 1,000 ft. MSL.
A-8	Over the Washington State University trailer at 5,000 ft. MSL.
A-9	Over San Pablo Bay at 1,000 ft. MSL.
A-10	East of Nichols at 800 ft. MSL.
A-11	East of Antioch at 900 ft. MSL.
A-12	Over Iselton at 900 ft. MSL.
A-13	Over 1-5 approximately 10 miles south of Sacramento at 600 ft. MSL.

TABLE C24. LOCATION OF AIRCRAFT COLLECTED HYDROCARBON SAMPLES ON SEPTEMBER 11, 1975

A-1	Over the Carquinez Strait, approximately 3 miles upwind of the Exxon refinery at 400 ft. MSL.
A-2	Near Tracy at 1,000 ft. MSL.
A-3	Near Lodi at 1,000 ft. MSL.
A-4	Approximately 10 miles downwind along the north shore of channel at 900 ft. MSL.
A-5	Approximately 10 miles downwind in middle of channel at 900 ft. MSL.
A-6	Approximately 10 miles downwind along the south shore of channel at 900 ft. MSL.
A-7	2 miles downwind along south shore of channel at 500 ft. MSL.
A-8	1 mile downwind of Exxon refinery, 2 passes through the plume at 500 ft. MSL.
A-9	1 mile downwind across the Exxon plume at 1,000 ft. MSL.
A-10	2 miles downwind along south shore of channel at 1,000 ft. MSL.
A-11	
A-12	
A-13	

TABLE C25. LOCATION OF AIRCRAFT COLLECTED HYDROCARBON SAMPLES ON SEPTEMBER 12, 1975

A-1	West of Petaluna at 1,200 ft. MSL.
A-2	15 miles SE of Antioch at 1,000 ft. MSL.
A-3	15 miles NE of Antioch at 1,000 ft. MSL.
A-4	5 miles north of Modesto at 1,000 ft. MSL.
A-5	
A-6	
A-7	
A-8	
A-9	
A-10	
A-11	
A-12	
A-13	

TABLE C26. LOCATION OF AIRCRAFT COLLECTED HYDROCARBON SAMPLES ON SEPTEMBER 13, 1975

A-1	Over the Washington State University trailer at 8,000 ft. MSL.
A-2	1 mile downwind of Phillips refinery at Avon in plume at 700 ft. MSL.
A-3	1 mile upwind of the Exxon refinery at 1,000 ft. MSL.
A-4	1 mile downwind of the Exxon refinery at 1,000 ft. MSL.
A-5	1 mile downwind of the Exxon refinery at 1,000 ft. MSL.
A-6	Between 0-3 miles downwind shooting the Exxon plume at 1,000 ft. MSL.
A-7	Between 0-3 miles downwind shooting the Exxon plume at 500 ft. MSL.
A-8	In plume along south shore of channel, (probably emissions from Avon and Martinez) at 500 ft. MSL.
A-9	1 mile upwind of Exxon refinery at 1,000 ft. MSL.
A-10	1 mile downwind of refinery in plume at 1,000 ft. MSL.
A-11	Between 0-3 miles downwind shooting the Exxon plume at 1,000 ft. MSL.
A-12	Between 0-3 miles downwind of the Phillips refinery at Avon shooting the plume at 1,300 ft. MSL.
A-13	

TABLE C27. LOCATION OF AIRCRAFT COLLECTED HYDROCARBON SAMPLES ON SEPTEMBER 14, 1975

A-1	Over the Washington State University trailer at 11,000 ft. MSL.
A-2	Over radio towers near Napa VOR at 1,200 ft. MSL.
A-3	Over the mountains NW of San Francisco at 1,700 ft. MSL.
A-4	Over the SE shore of San Pablo Bay, downwind of Standard Oil refinery at Richmond at 1,000 ft. MSL.
A-5	Over Carquinez Strait approximately 3 miles upwind of the Exxon refinery.
A-6	Over San Pablo Bay, downwind of Standard Oil refinery at Richmond at 1,000 ft. MSL.
A-7	Near Pittsburgh at 1,000 ft. MSL.
A-8	15 miles SE of Antioch at 1,000 ft. MSL.
A-9	15 mile NE of Antioch at 1,000 ft. MSL.
A-10	Approximately 5 miles north of Modesto at 1,000 ft. MSL.
A-11	NW of cooling towers near Clay at 1,000 ft. MSL.
A-12	
A-13	

TABLE C28. LOCATION OF AIRCRAFT COLLECTED HYDROCARBON SAMPLES ON SEPTEMBER 15, 1975

A-1	Over the Washington State University trailer at 1,200 ft. MSL.
A-2	Over Napa VOR at 1,000 ft. MSL.
A-3	Along Pacific coast NW of San Francisco at 1,500 ft. MSL.
A-4	West of Standard Oil refinery at Richmond at 1,000 ft. MSL.
A-5	Over Carquinez Strait along south shore, approximately 3 miles upwind of Exxon refinery at 1,000 ft. MSL.
A-6	Near Pittsburgh at 1,000 ft. MSL.
A-7	Over Discovery Bay, east of Antioch at 1,100 ft. MSL.
A-8	Near Terminous at 1,100 ft. MSL.
A-9	Approximately 10 miles north of Modesto at 1,100 ft. MSL.
A-10	Over the cooling towers at Clay at 1,300 ft. MSL.
A-11	
A-12	
A-13	

TABLE C29. LOCATION OF AIRCRAFT COLLECTED HYDROCARBON SAMPLES ON SEPTEMBER 16, 1975

A-1	Over the Washington State University trailer at 8,000 ft. MSL.
A-2	2 miles upwind of Exxon refinery at 1,100 ft. MSL.
A-3	6 miles downwind across Exxon plume at 500 ft. MSL.
A-4	6 miles downwind across Exxon plume at 800 ft. MSL.
A-5	3 miles downwind across Exxon plume at 800 ft. MSL.
A-6	3 miles downwind across Exxon plume at 500 ft. MSL.
A-7	3 miles downwind across Exxon plume at 1,000 ft. MSL.
A-8	3 miles downwind across Exxon plume at 1,200 ft. MSL.
A-9	3 miles west of Reo Vista at 1,000 ft. MSL.
A-10	2 miles downwind of Exxon refinery at 1,000 ft. MSL.
A-11	
A-12	
A-13	

TABLE C30. LOCATION OF GROUND LEVEL HYDROCARBON SAMPLES ON SEPTEMBER 12, 1975

G-1	Along highway 160 @ 10:15
G-2	Brentwood, Calif. @ 11:50
G-3	Western side of Pittsburgh, Calif. @ 12:30
G-4	
G-5	
G-6	
G-7	
G-8	
G-9	
G-10	
G-11	
G-12	
G-13	

TABLE C31. LOCATION OF GROUND LEVEL HYDROCARBON SAMPLES ON SEPTEMBER 11, 1975

G-1	Sherman Island @ 1855
G-2	
G-3	
G-4	
G-5	
G-6	
G-7	
G-8	
G-9	
G-10	
G-11	
G-12	
G-13	

TABLE C32. LOCATION OF GROUND LEVEL HYDROCARBON SAMPLES ON SEPTEMBER 12, 1975

G-1	Rockville, Calif. @ 1830
G-2	Washington State University trailer site @ 1430
G-3	
G-4	
G-5	
G-6	
G-7	
G-8	
G-9	
G-10	
G-11	
G-12	
G-13	

TABLE C33. LOCATION OF GROUND LEVEL HYDROCARBON SAMPLES ON SEPTEMBER 13,1975

G-1	Rodeo, Calif. @ 1330
G-2	Rutherford, Calif. @ 1515
G-3	Sonoma, Calif. @ 1700
G-4	
G-5	
G-6	
G-7	
G-8	
G-9	
G-10	
G-11	
G-12	
G-13	

TABLE C34. LOCATION OF GROUND LEVEL HYDROCARBON SAMPLES ON SEPTEMBER 14, 1975

G-1	Along Frontage Road just downwind of the refinery in the Exxon plume @ 0830
G-2	Main Grizzly Island @ 1625
G-3	Middle Grizzly Island @ 1700
G-4	
G-5	
G-6	
G-7	
G-8	
G-9	
G-10	
G-11	
G-12	
G-13	

TABLE C35. LOCATION OF GROUND LEVEL HYDROCARBON SAMPLES ON SEPTEMBER 15, 1975

G-1	∿ 0.5 mile downwind of the refinery in the Exxon plume @ 0830
G-2	
G-3	
G-4	
G-5	
G-6	
G-7	
G-8	
G-9	
G-10	
G-11	
G-12	
G-13	

TABLE C36. LOCATION OF GROUND LEVEL HYDROCARBON SAMPLES ON SEPTEMBER 16, 1975

G-1	Washington State University trailer site @ 1000
G-2	∿ 0.5 mile downwind of the refinery in the Exxon plume @ 9000
G-3	
G-4	
G-5	
G-6	
G-7	
G-8	
G-9	
G-10	
G-11	
G-12	
G-13	

TABLE C37. LOCATION OF GROUND LEVEL HYDROCARBON SAMPLES ON SEPTEMBER 17, 1975

G-1	∿ 0.5 mile downwind of refinery in the Exxon plume @ 0830
G-2	Washington State University trailer site @ 0930
G-3	
G-4	
G-5	
G-6	
G-7	
G-8	
G-9	
G-10	
G-11	
G-12	
G-13	

TABLE C38. LOCATION OF GROUND LEVEL HYDROCARBON SAMPLES ON SEPTEMBER 18, 1975

G-1	∿ 0.5 mile downwind of refinery in the Exxon plume
G-2	Washington State University trailer site @ 1030
G-3	
G-4	
G-5	
G-6	
G-7	
G-8	
G-9	
G-10	
G-11	
G-12	
G-13	

TABLE C39. LOCATION OF GROUND LEVEL HYDROCARBON SAMPLES ON SEPTEMBER 19, 1975

G-1	∿ 0.5 mile downwind of refinery in the Exxon plume @ 0930
G-2	Washington State University trailer site @ 1000
G-3	West end of Exxon refinery
G-4	Middle of Exxon refinery
G-5	East end of Exxon refinery
G-6	Parking Garage
G-7	Parking Lot
G-8	
G-9	
G-10	
G-11	
G-12	
G-13	

TABLE C40. LOCATION OF GROUND LEVEL HYDROCARBON SAMPLES ON SEPTEMBER 20, 1975

G-1	Washington State University trailer site @ 0900
G-2	∿ 0.5 mile downwind of refinery in the Exxon plume @ 0930
G-3	
G-4	
G-5	
G-6	
G-7	
G-8	
G-9	
G-10	
G-11	
G-12	
G-13	

APPENDIX D

This section summarizes results from all natural sunlight bag irradiation experiments conducted during the field study. Individual plots of variations in O_3, NO and NO_2 versus irradiation time are provided for each experiment.

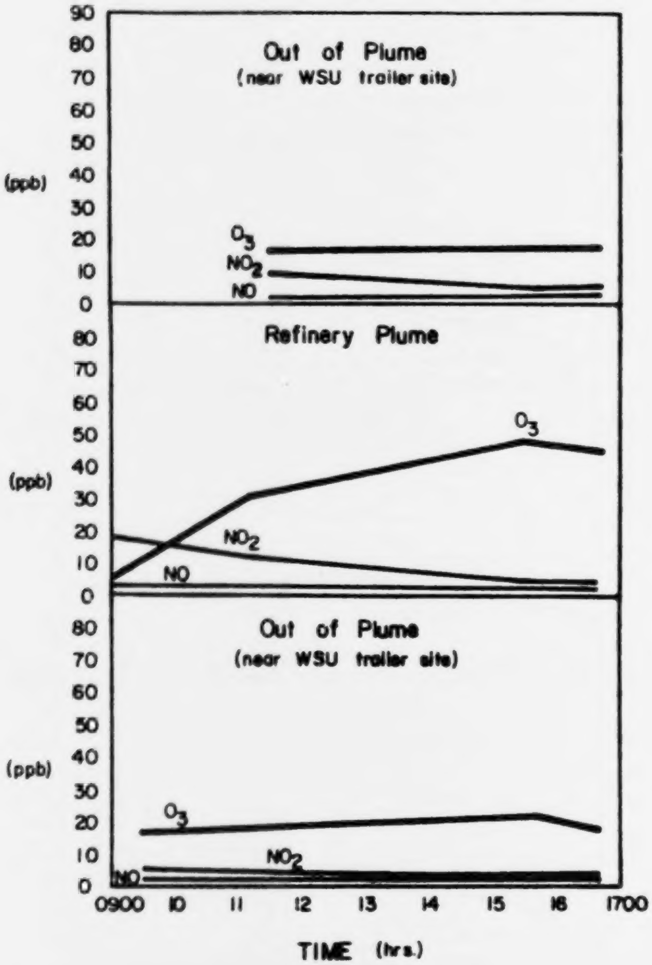

Figure D1. Plot of O_3, NO_2 and NO versus irradiation time for captive air irradiation experiments on September 14, 1975.

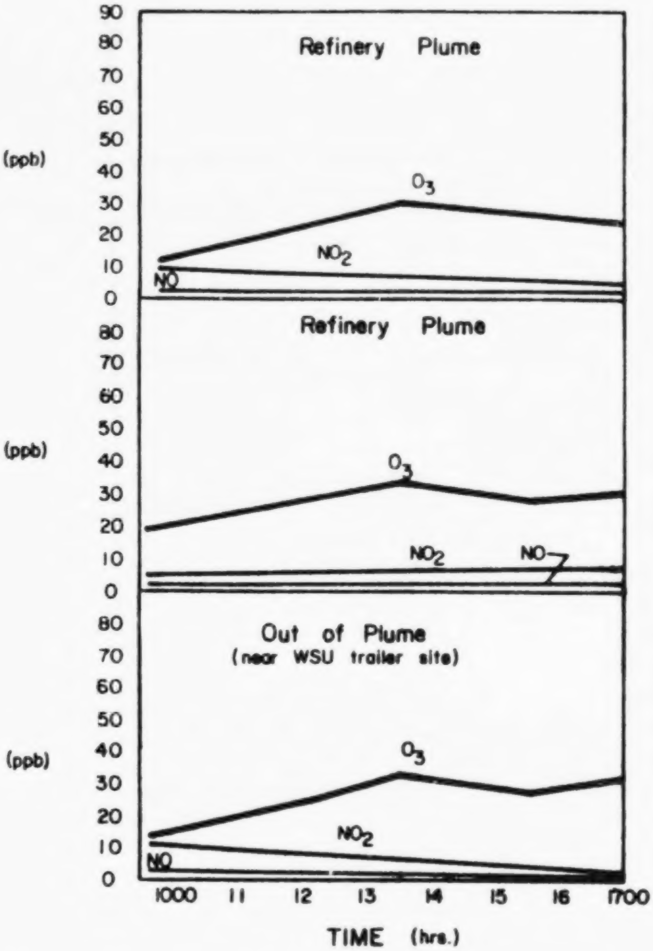

Figure D2. Plot of O_3, NO_2 and NO versus irradiation time for captive air irradiation experiments on September 15, 1975.

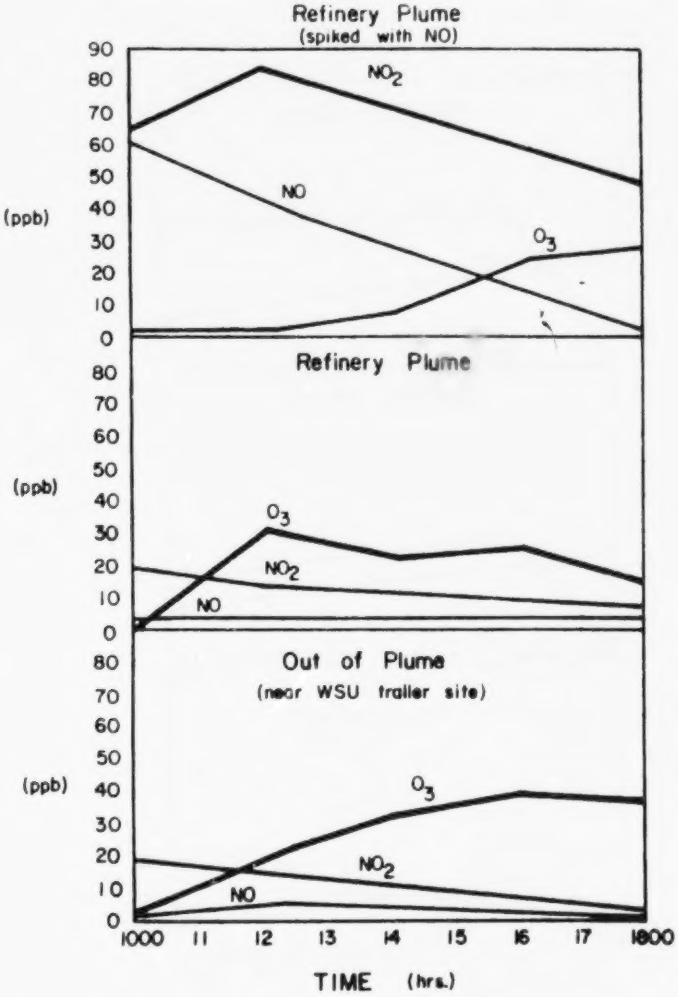

Figure D3. Plot of O_3, NO_2 and NO versus irradiation time for captive air irradiation experiments on September 16, 1975.

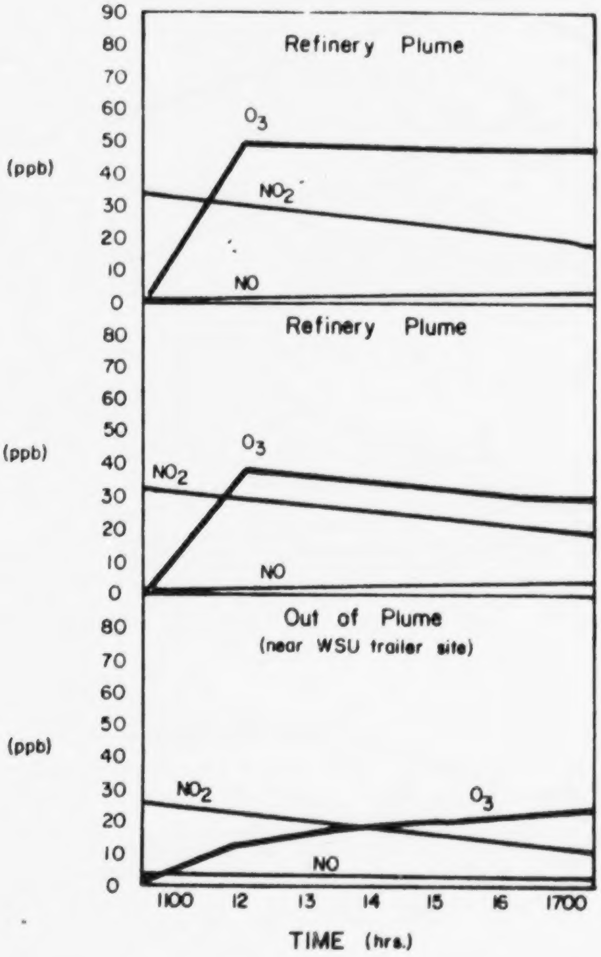

Figure D4. Plot of O_3, NO_2 and NO versus irradiation time for captive air irradiation experiments on September 17, 1975.

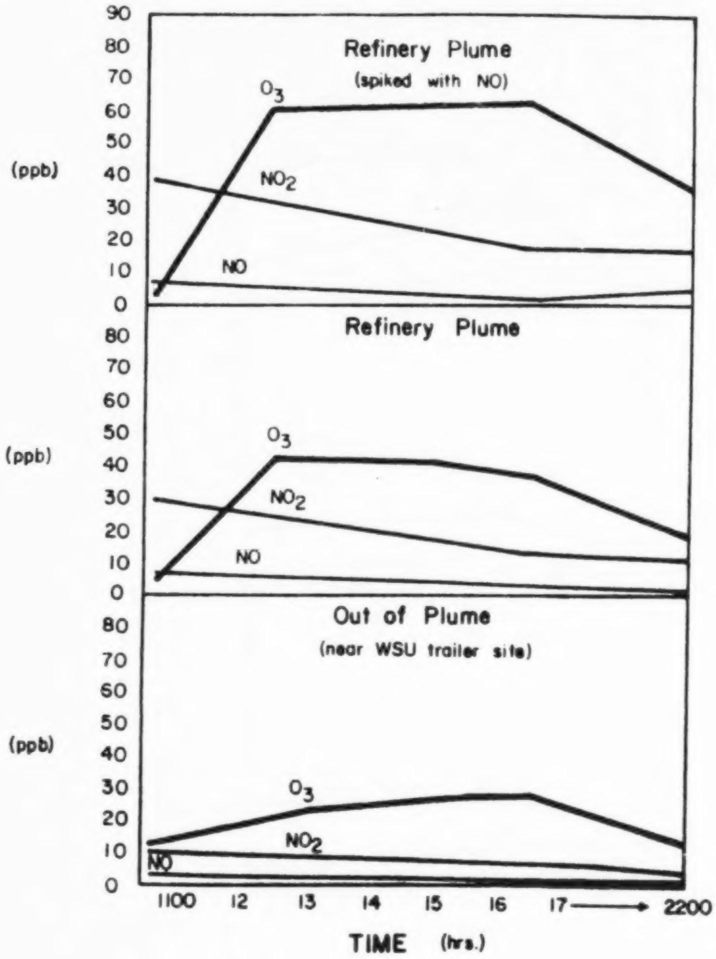

Figure D5. Plot of O_3, NO_2 and NO versus irradiation time for captive air irradiation experiments on September 18, 1975.

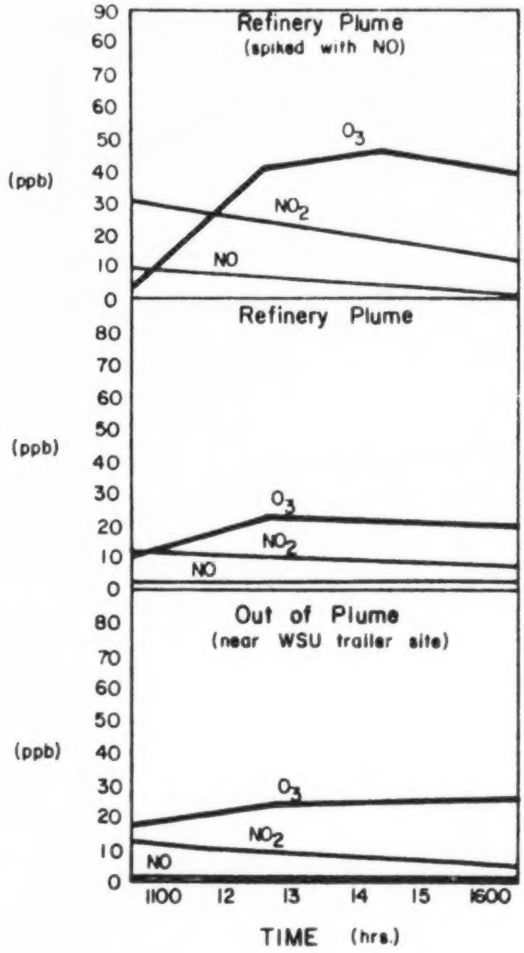

Figure D6. Plot of O_3, NO_2 and NO versus irradiation time for captive air irradiation experiments on September 19, 1975.

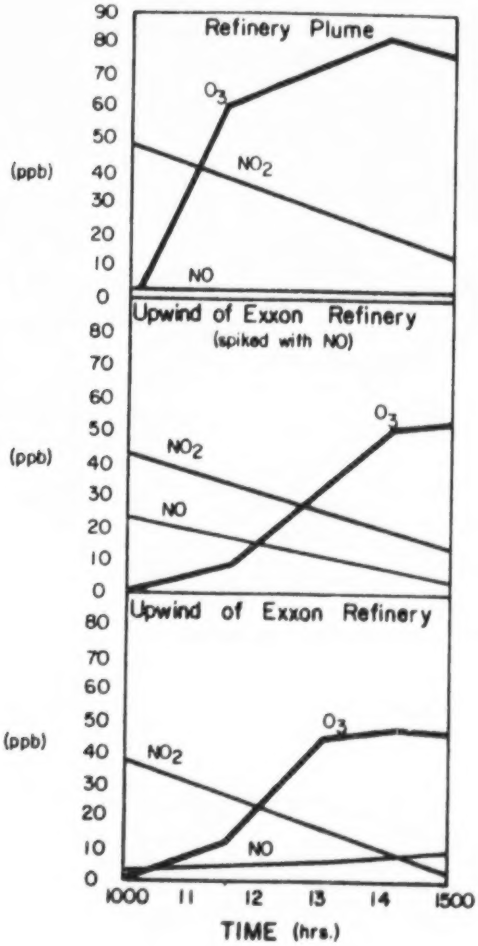

Figure D7. Plot of O_3, NO_2 and NO versus irradiation time for captive air irradiation experiments on September 20, 1975.

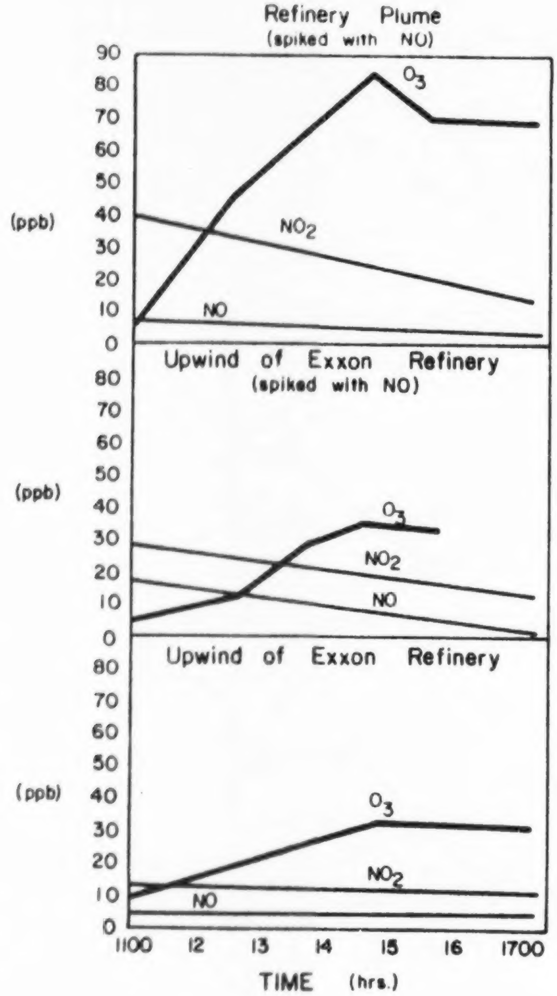

Figure D8. Plot of O_3, NO_2 and NO versus irradiation time for captive air irradiation experiments on September 21, 1975.

APPENDIX E

Acoustical sounder traces recorded between 9/5/75 and 9/21/75 are contained in this section. The acoustical radar was located adjacent to the WSU field laboratory, approximately 1.5 miles east of the Exxon refinery.

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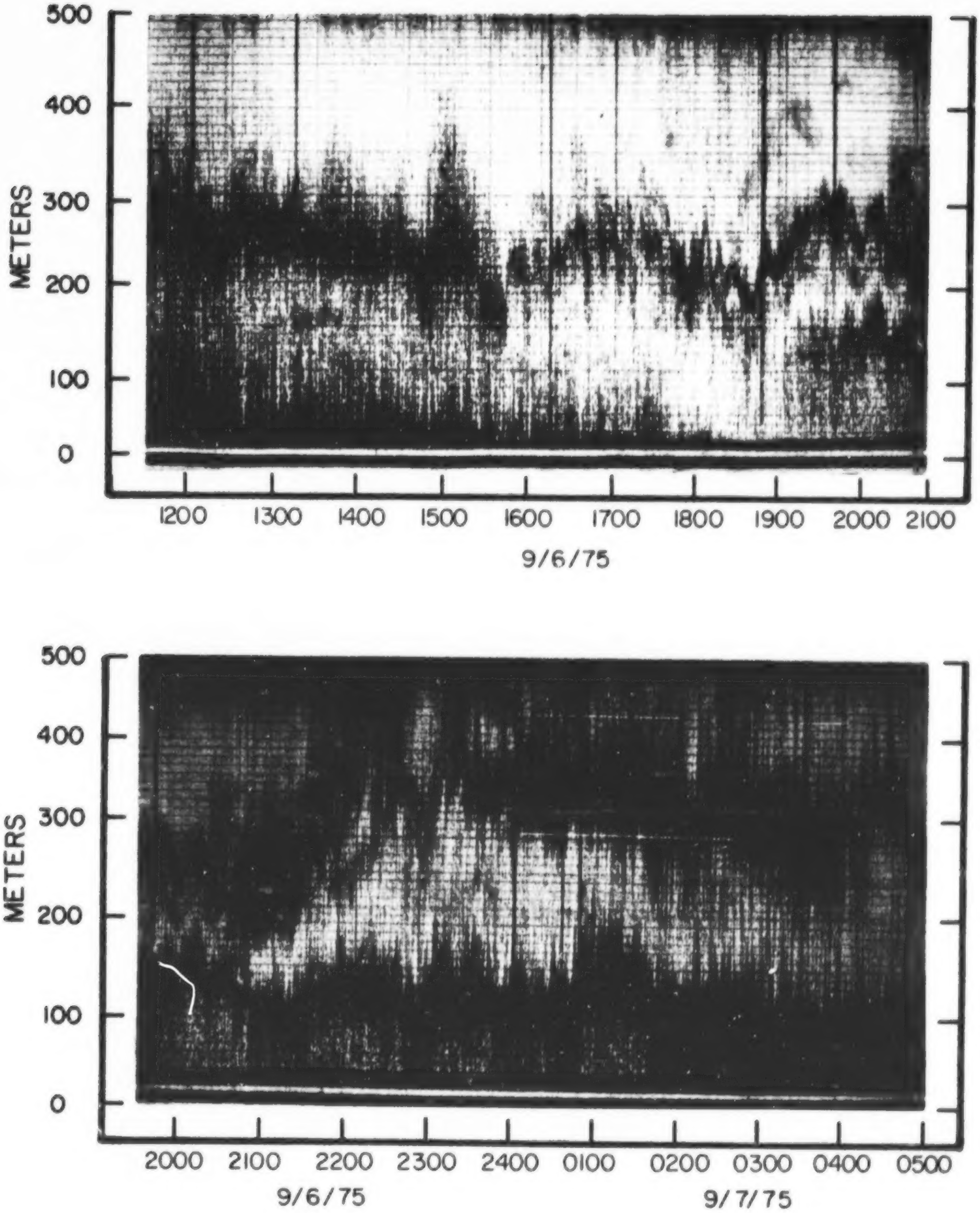

Figure E1. Acoustical Sounder tracers recorded on 9/6/75 and 9/7/75.

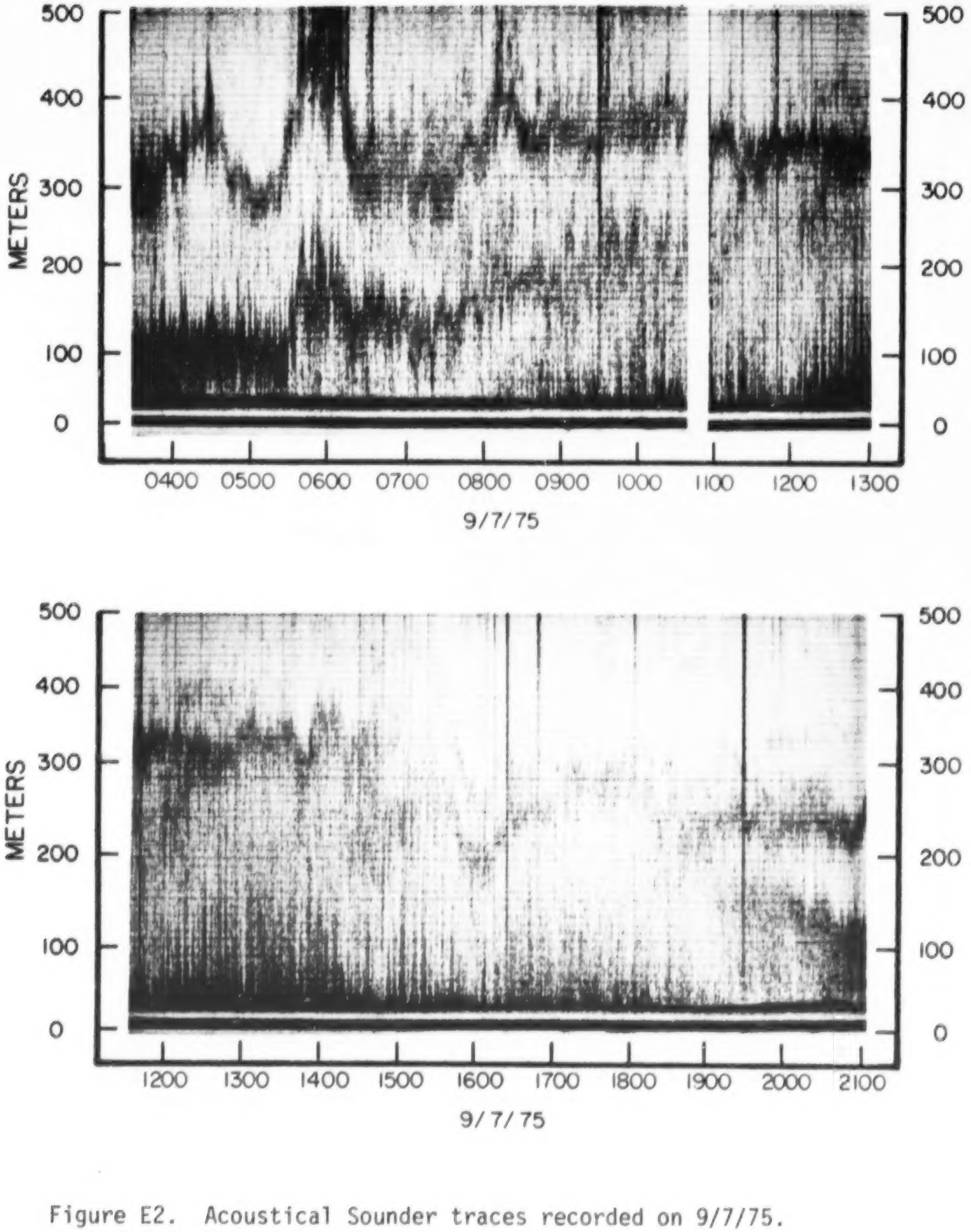

Figure E2. Acoustical Sounder traces recorded on 9/7/75.

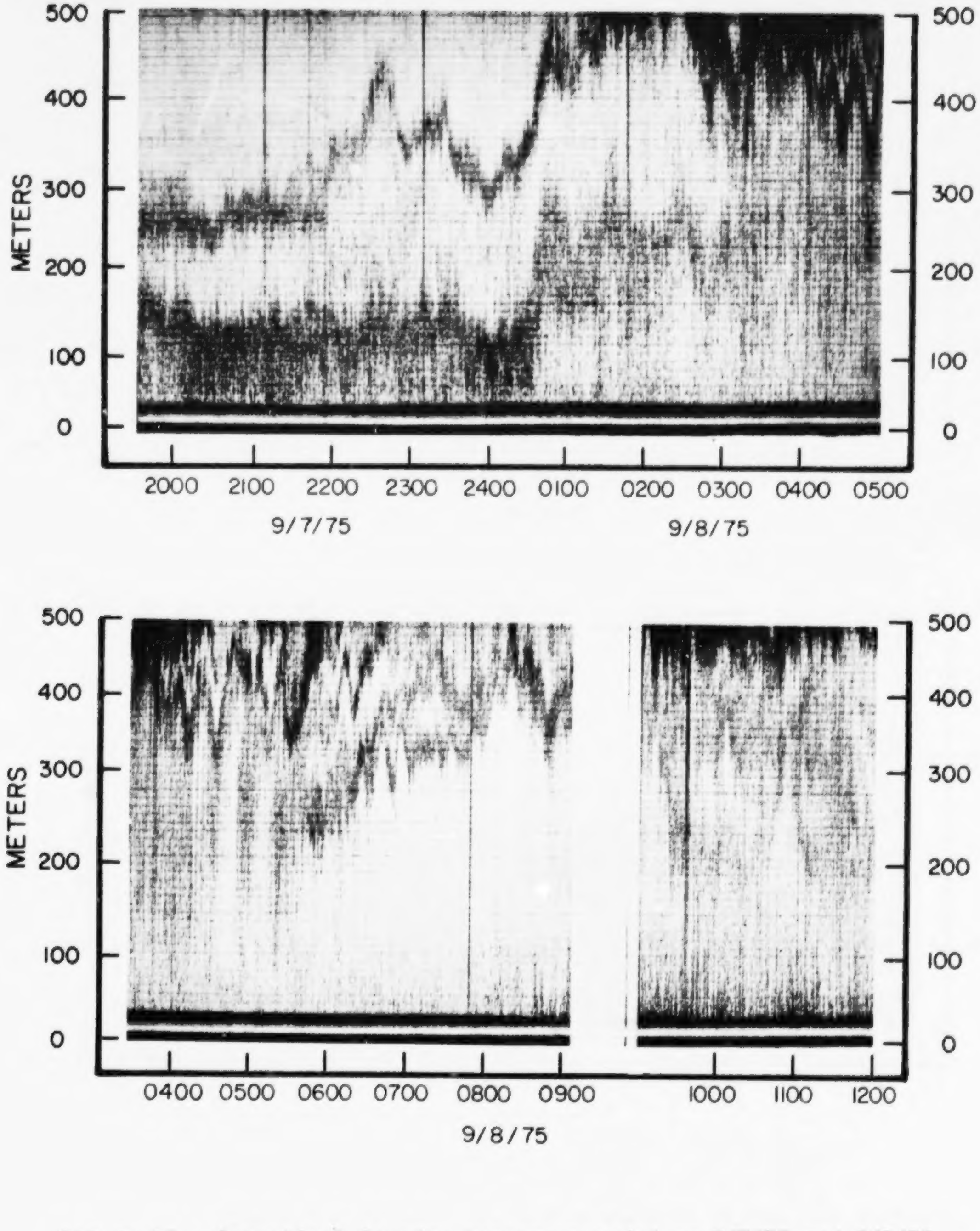

Figure E3. Acoustical Sounder traces recorded on 9/7/75 and 9/8/75.

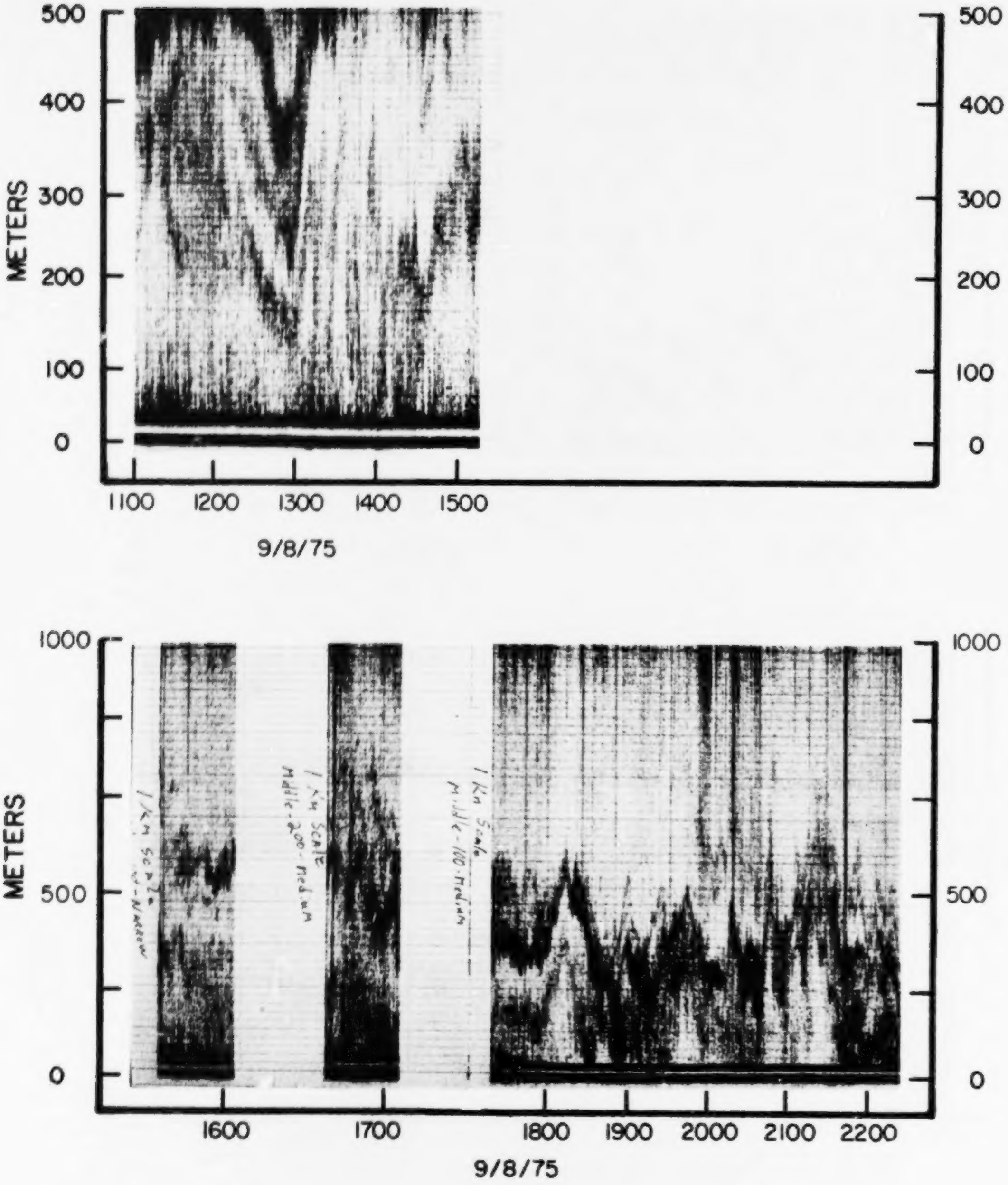

Figure E4. Acoustical Sounder traces recorded on 9/8/75.

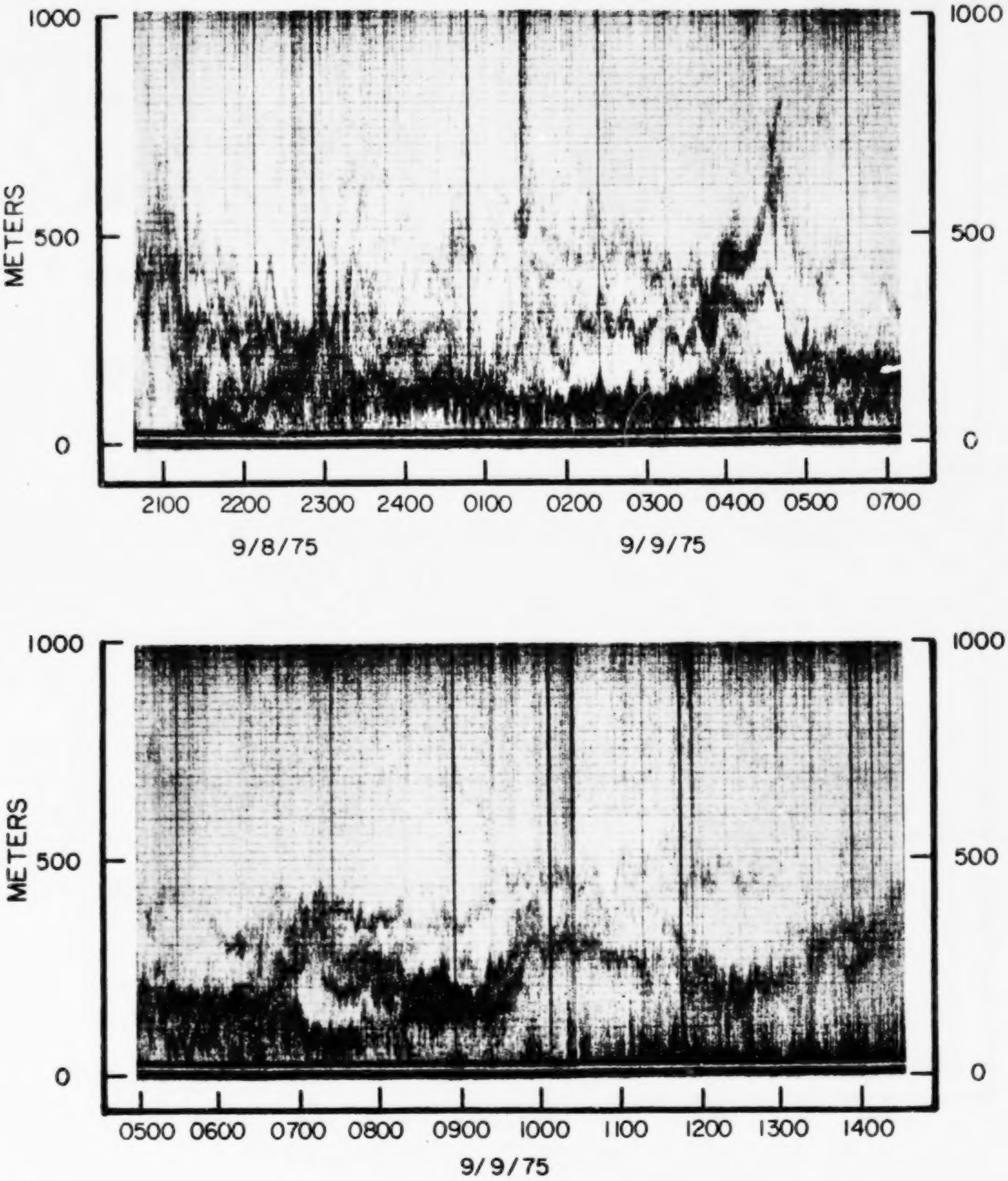

Figure E 5. Acoustical Sounder traces recorded on 9/8 /75 and 9/9 /75.

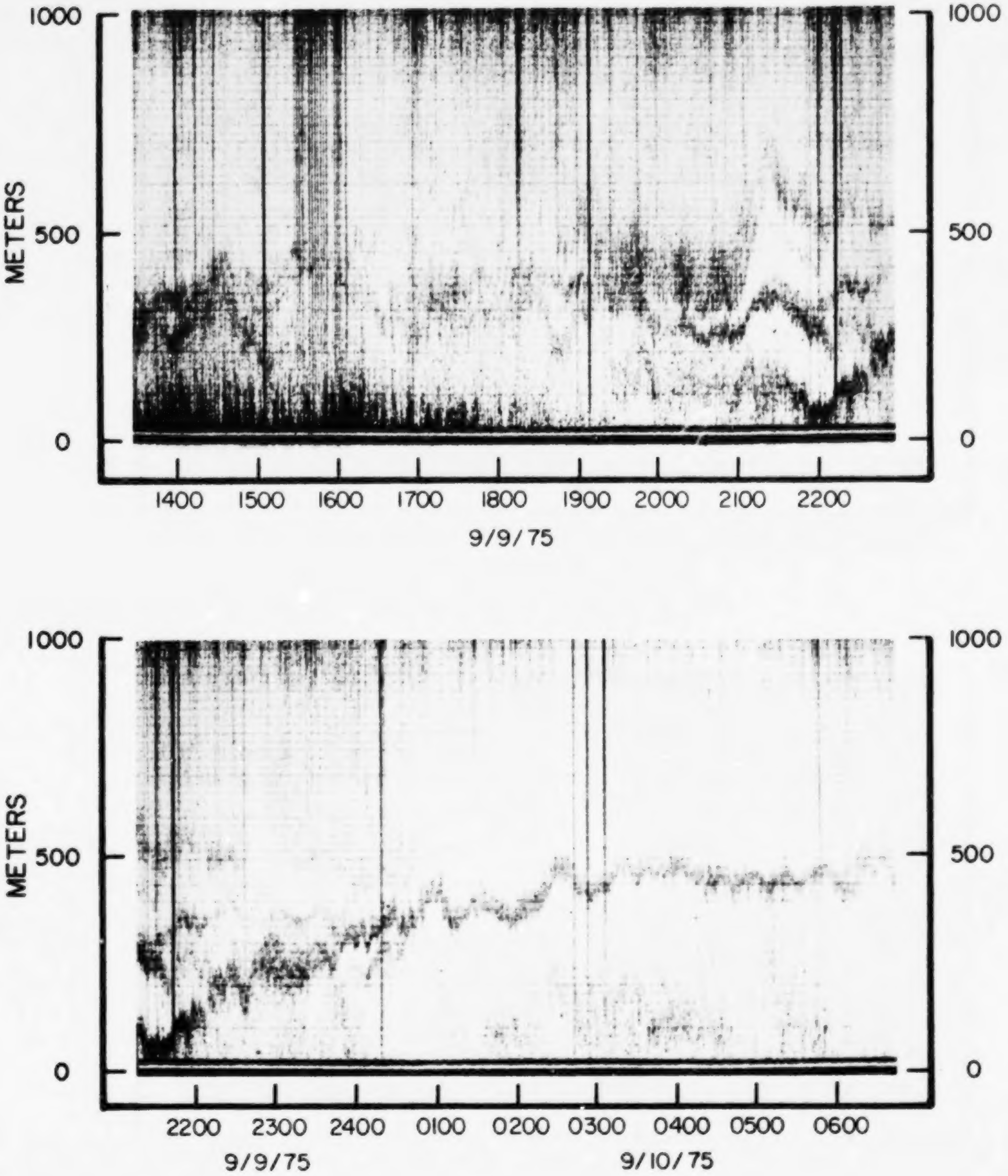

Figure E6. Acoustical Sounder traces recorded on 9/9/75 and 9/10/75.

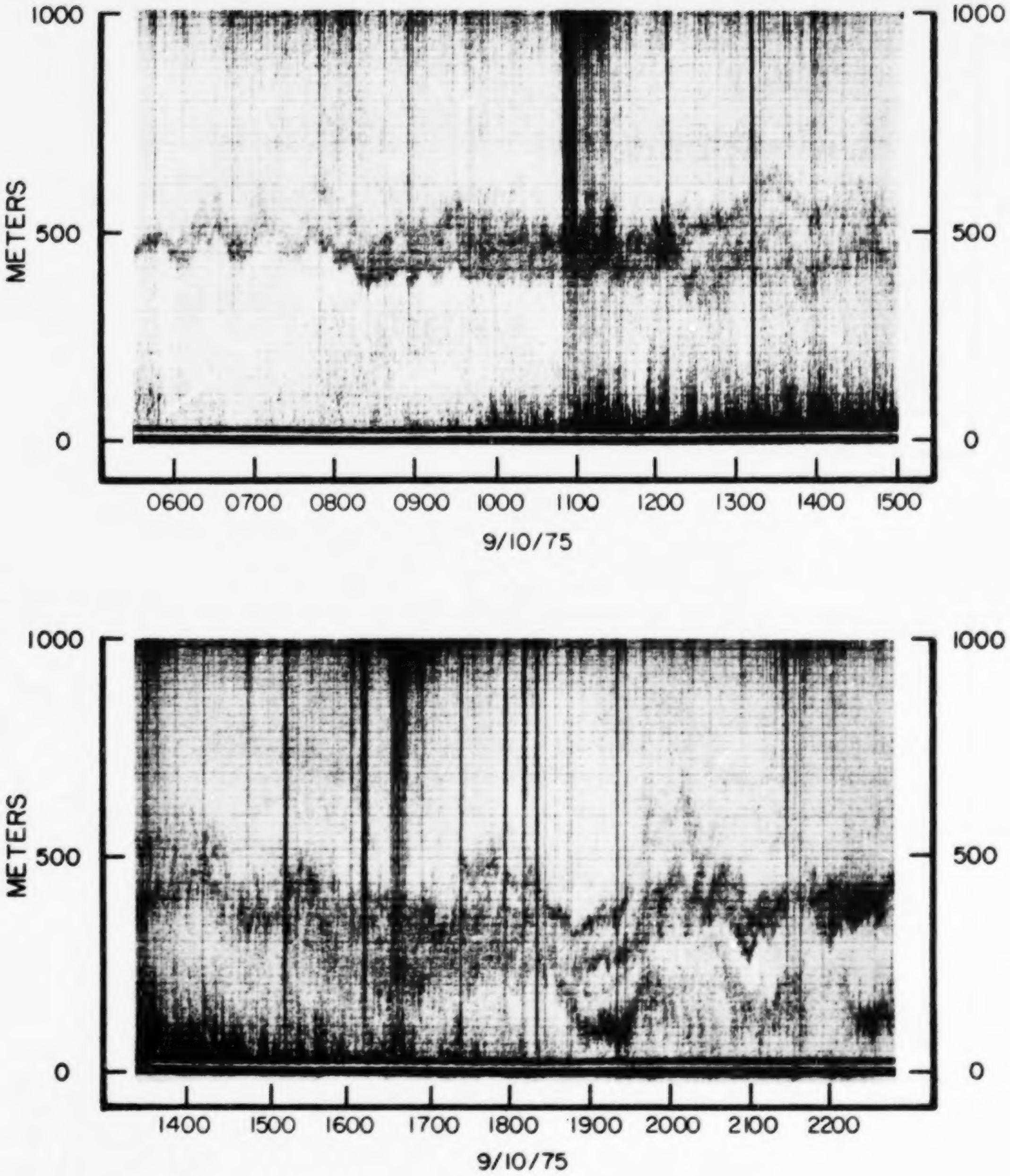

Figure E7. Acoustical Sounder traces recorded on 9/10/75.

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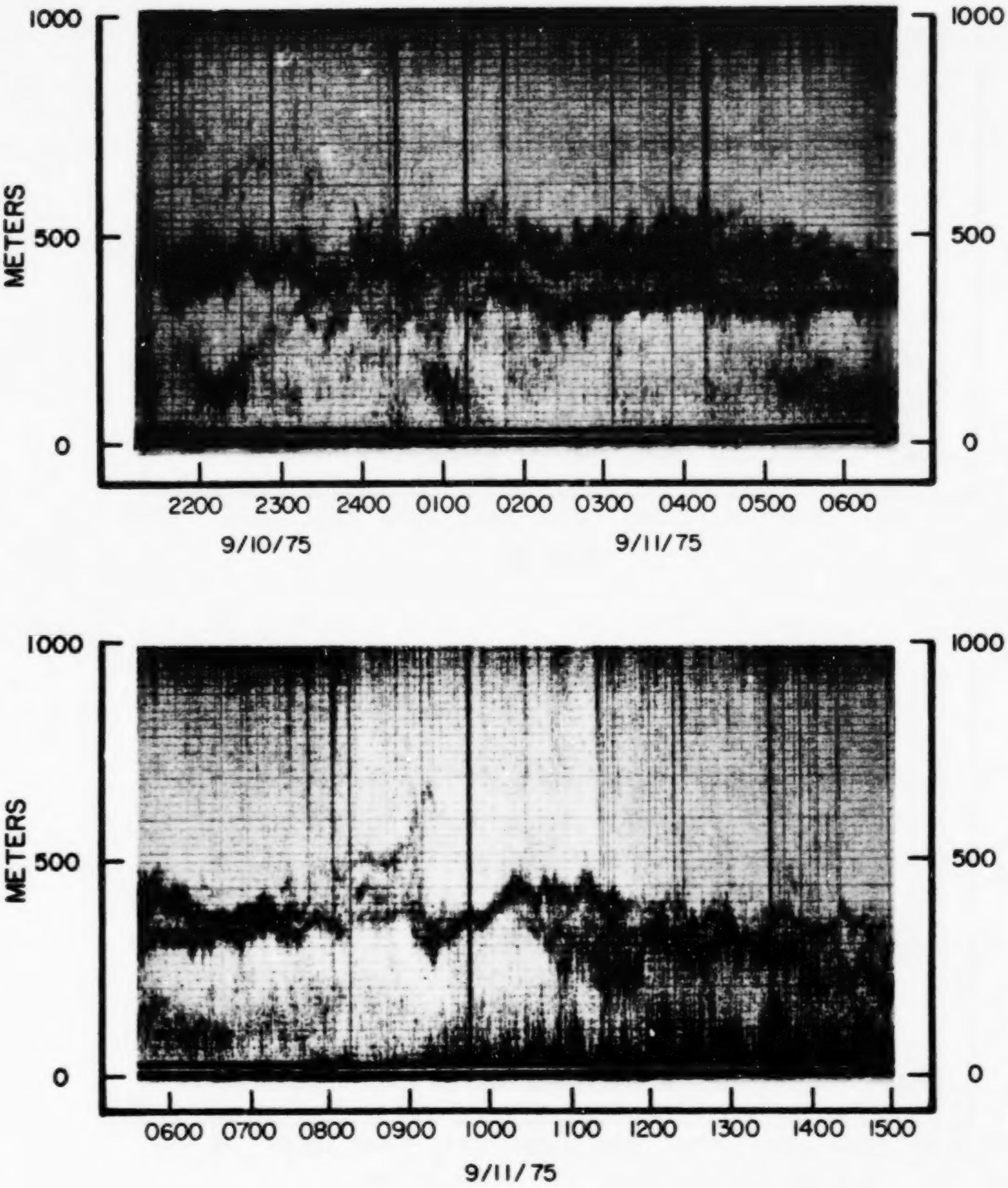

Figure E8. Acoustical Sounder traces recorded on 9/10/75 and 9/11/75.

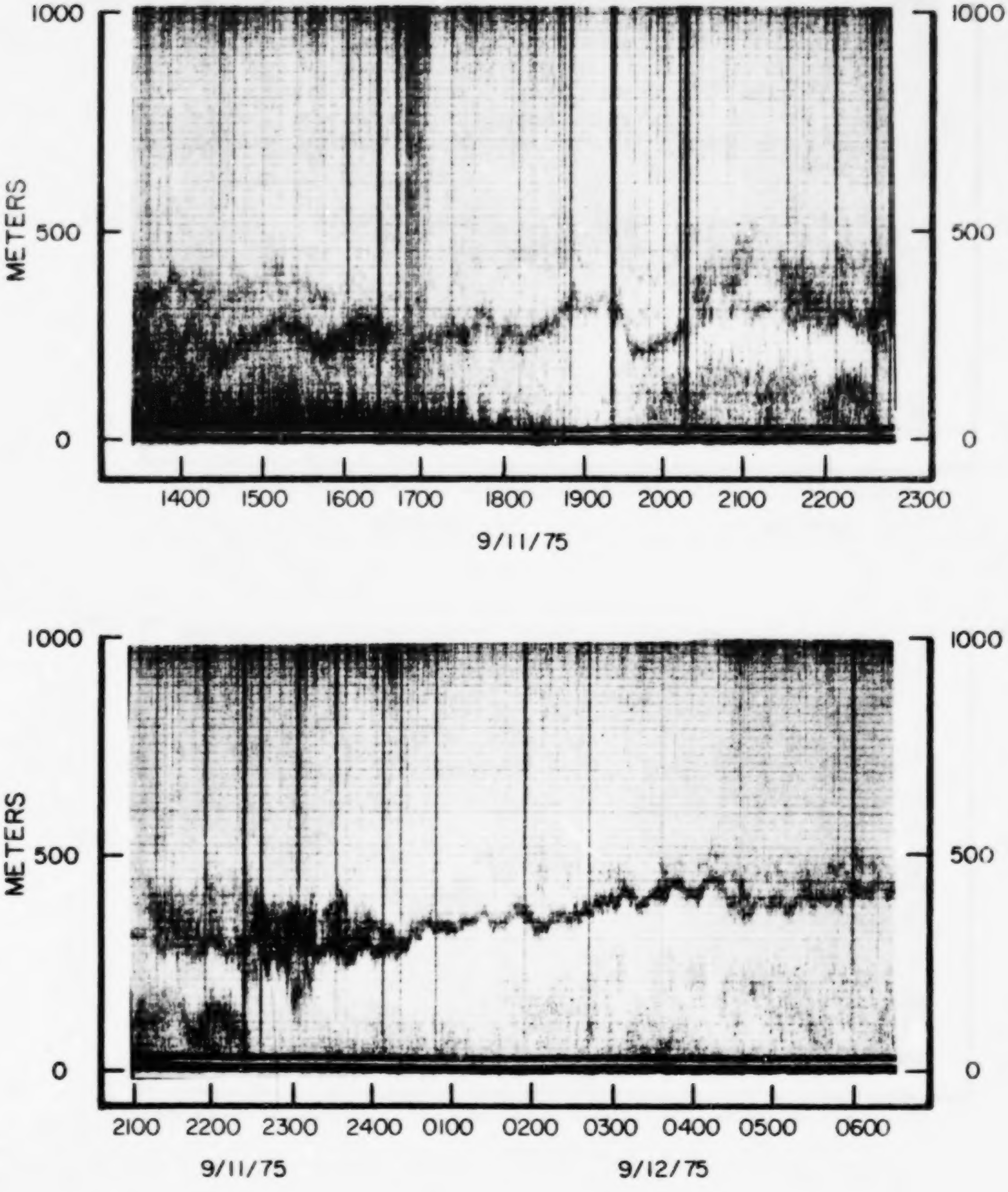

Figure E9. Acoustical Sounder traces recorded on 9/11/75 and 9/12/75.

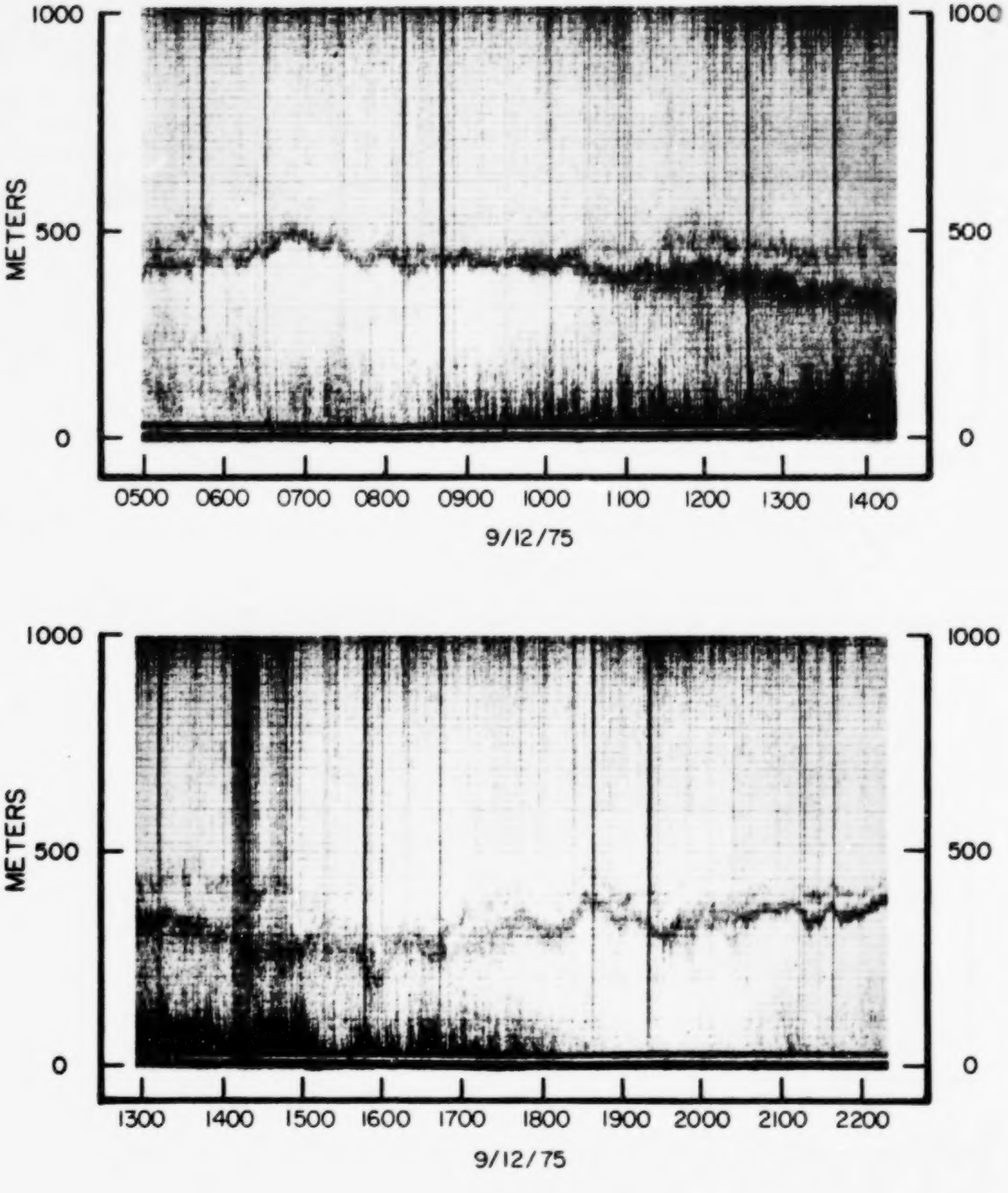

Figure E10. Acoustical Sounder traces recorded on 9/12/75.

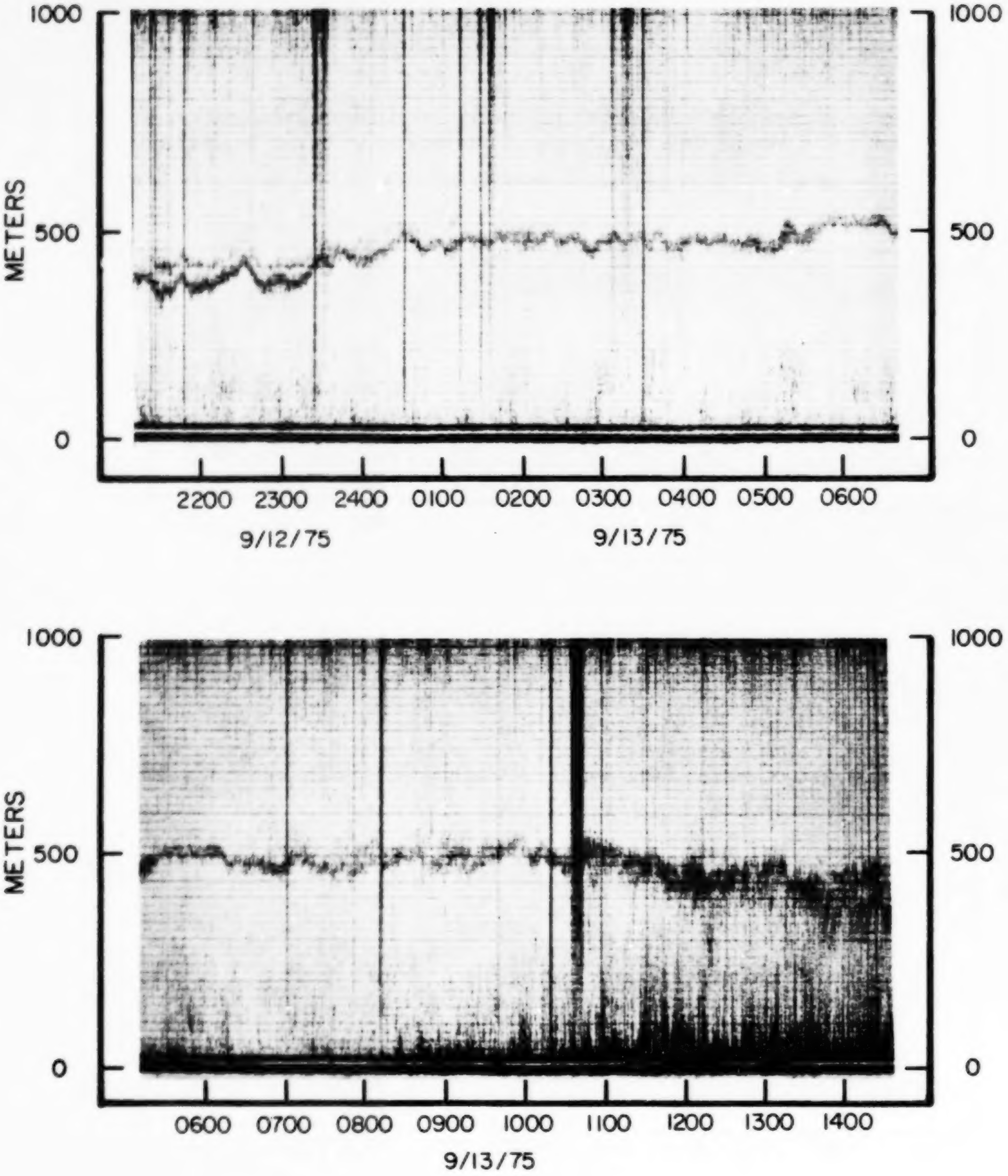

Figure E11. Acoustical Sounder traces recorded on 9/12/75 and 9/13/75.

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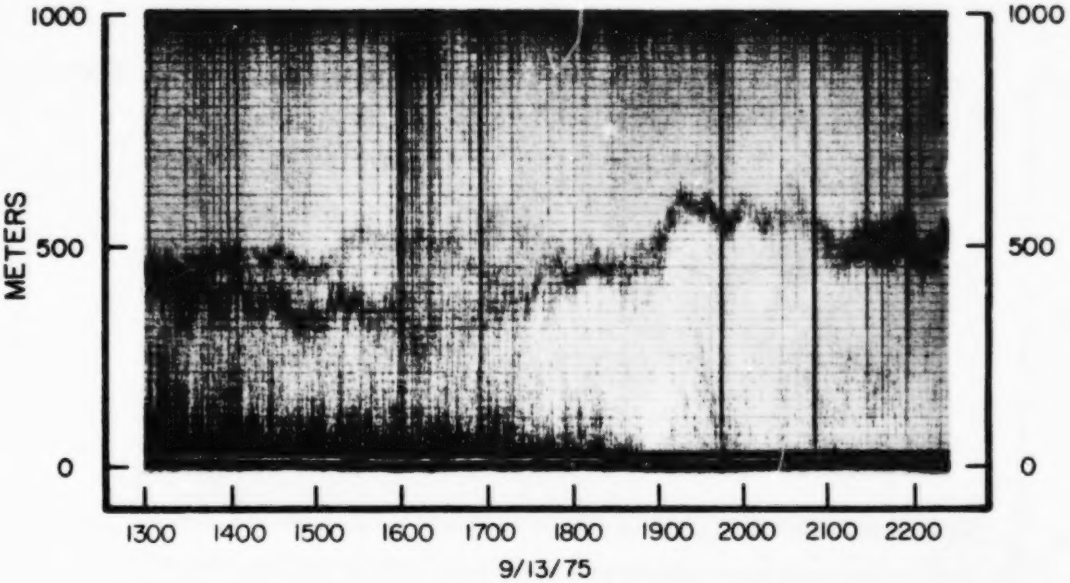


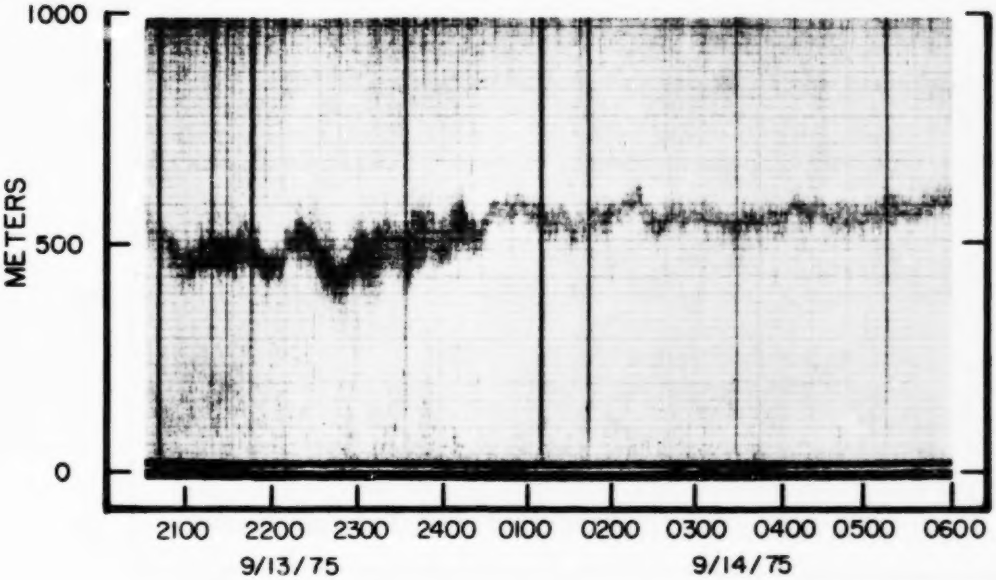


Figure E12. Acoustical Sounder traces recorded on 9/13/75 and 9/14/75.

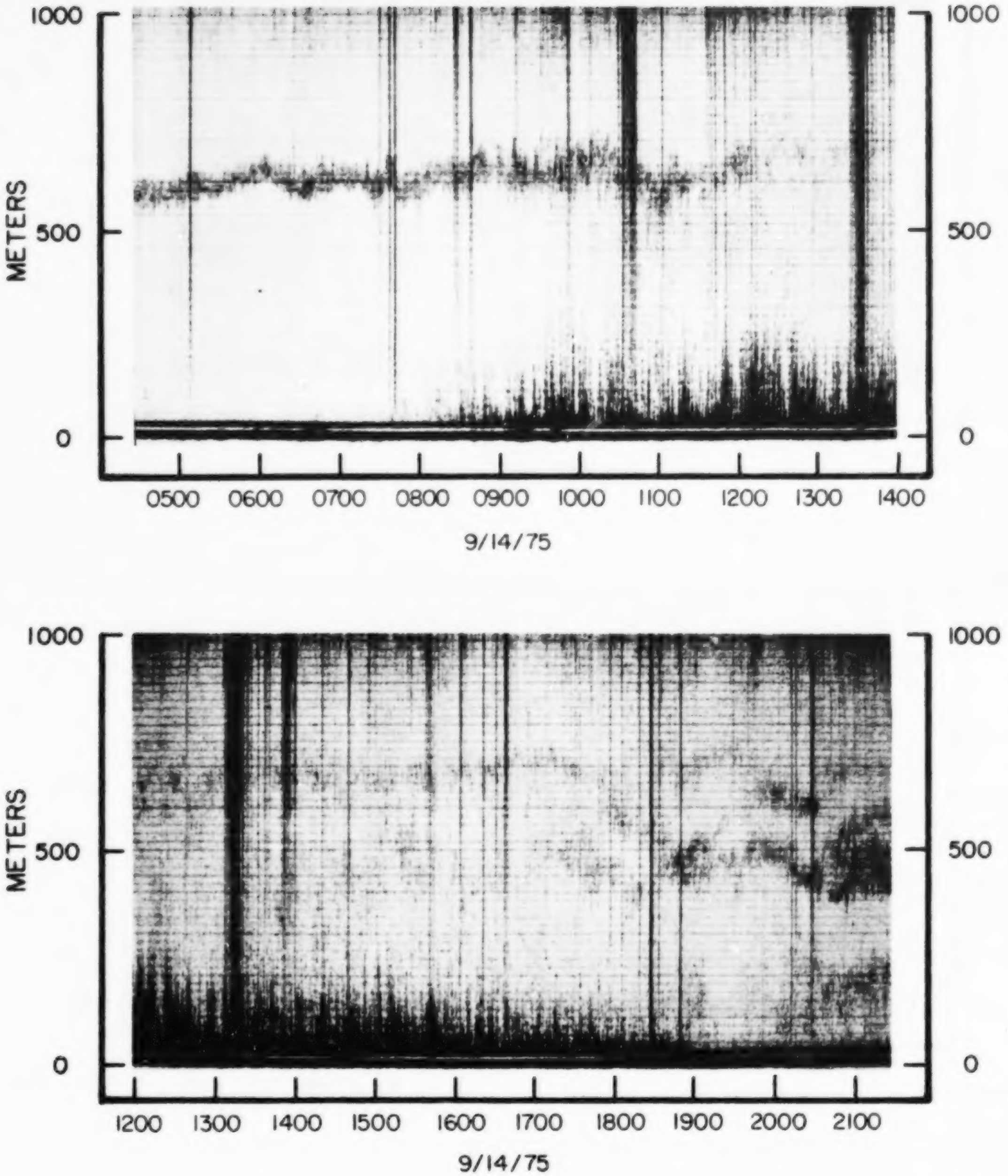


Figure E13. Acoustical Sounder traces recorded on 9/14/75.

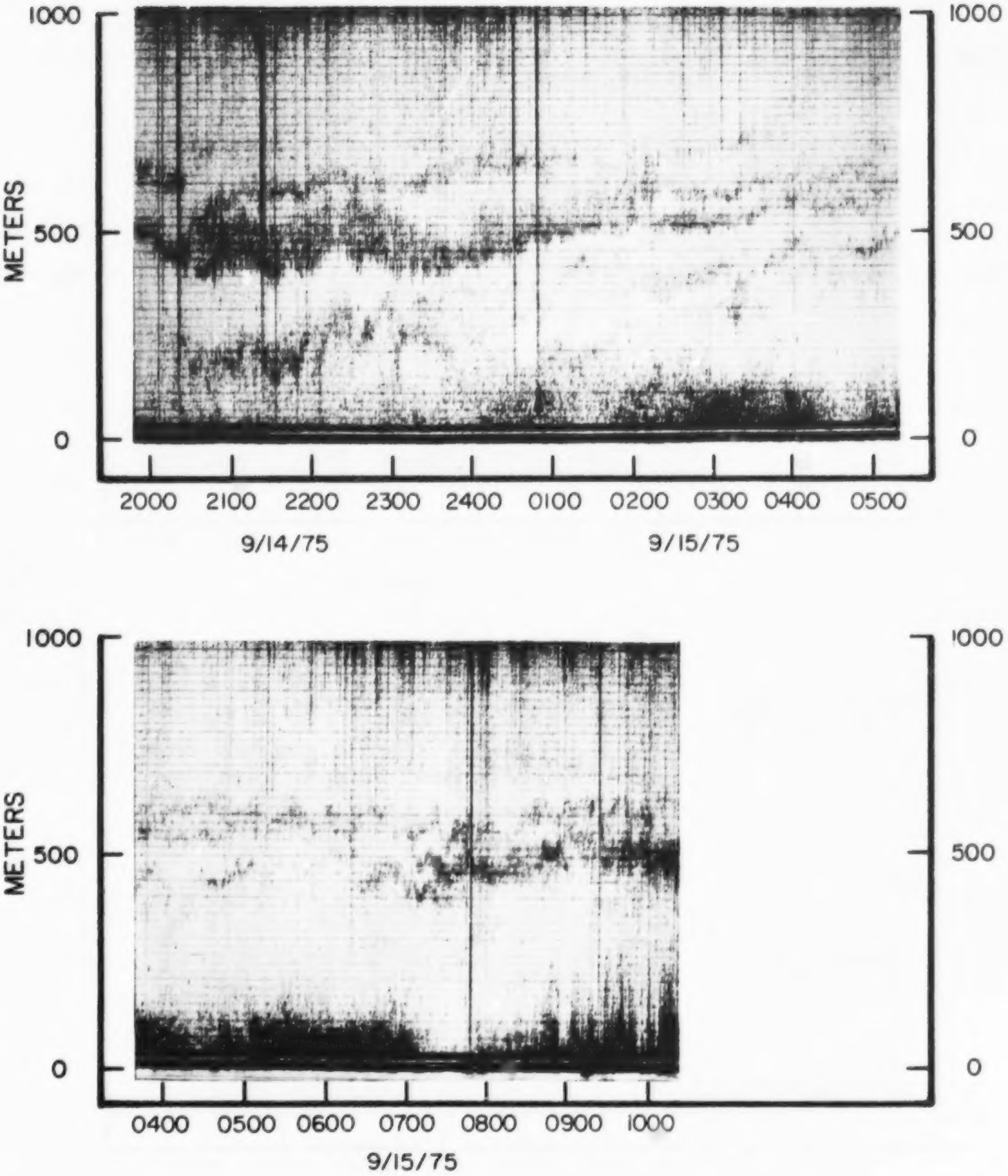


Figure E14. Acoustical Sounder traces recorded on 9/14/75 and 9/15/75.

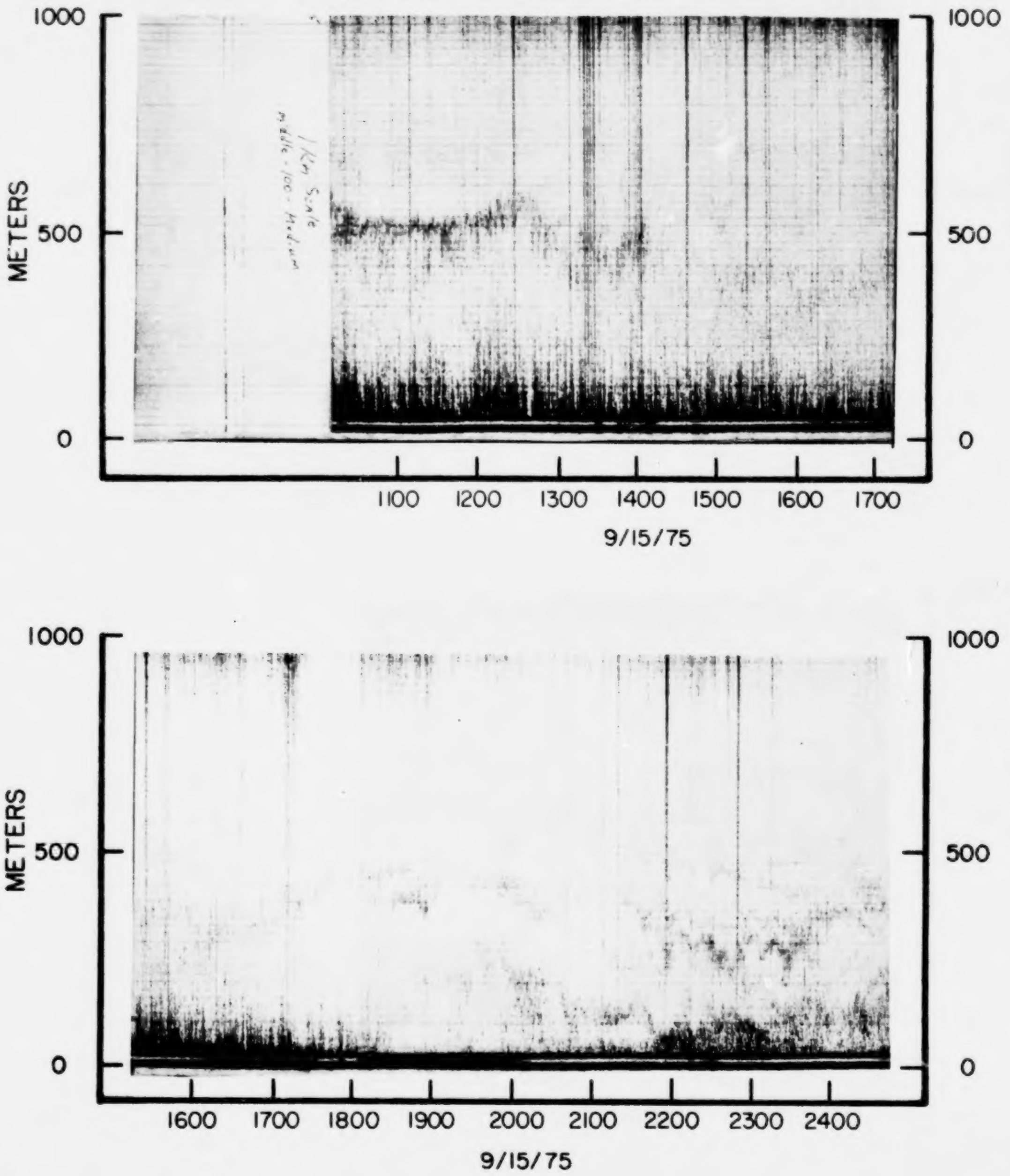


Figure E15. Acoustical Sounder traces recorded on 9/15/75.

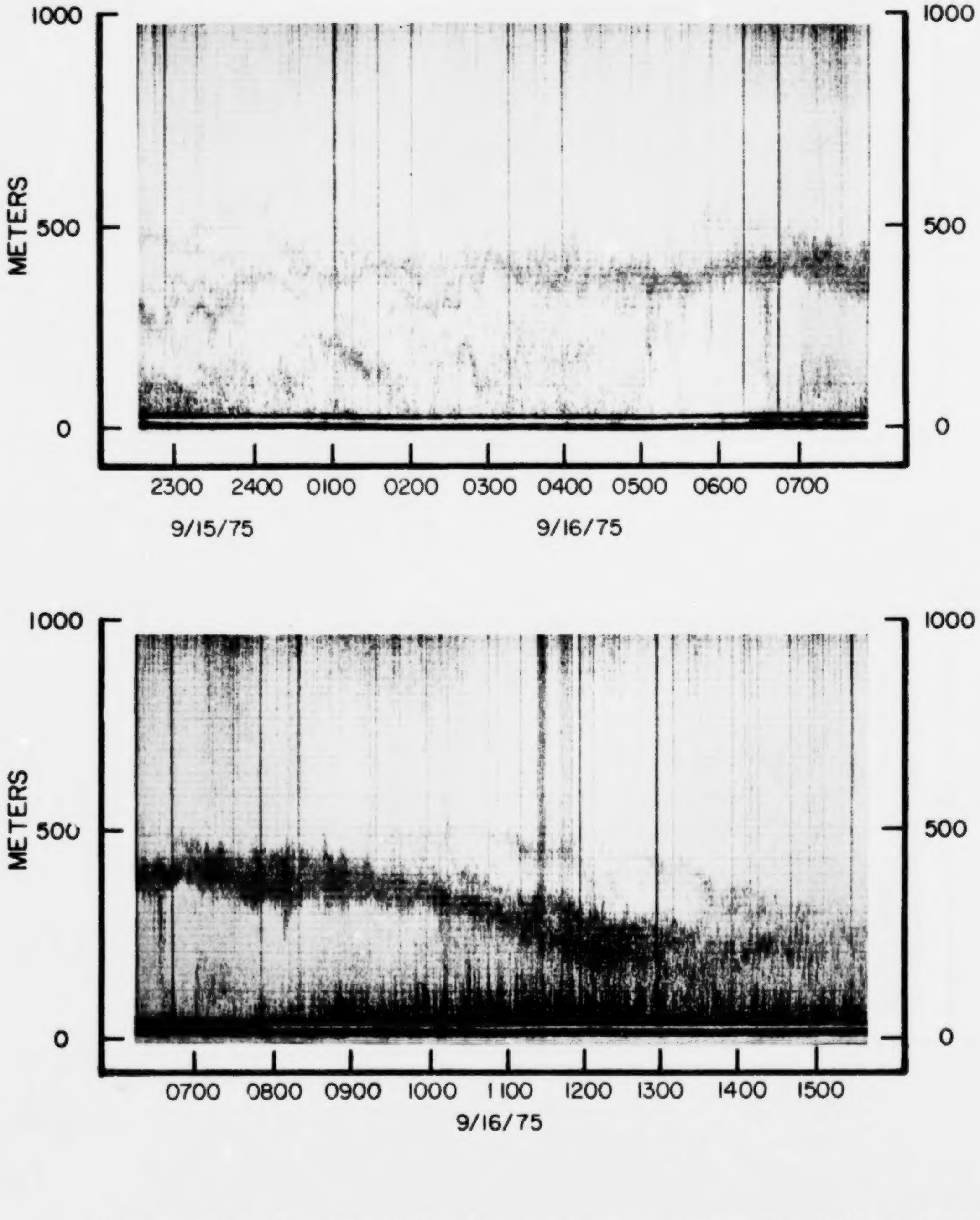


Figure E16. Acoustical Sounder traces recorded on 9/15/75 and 9/16/75.

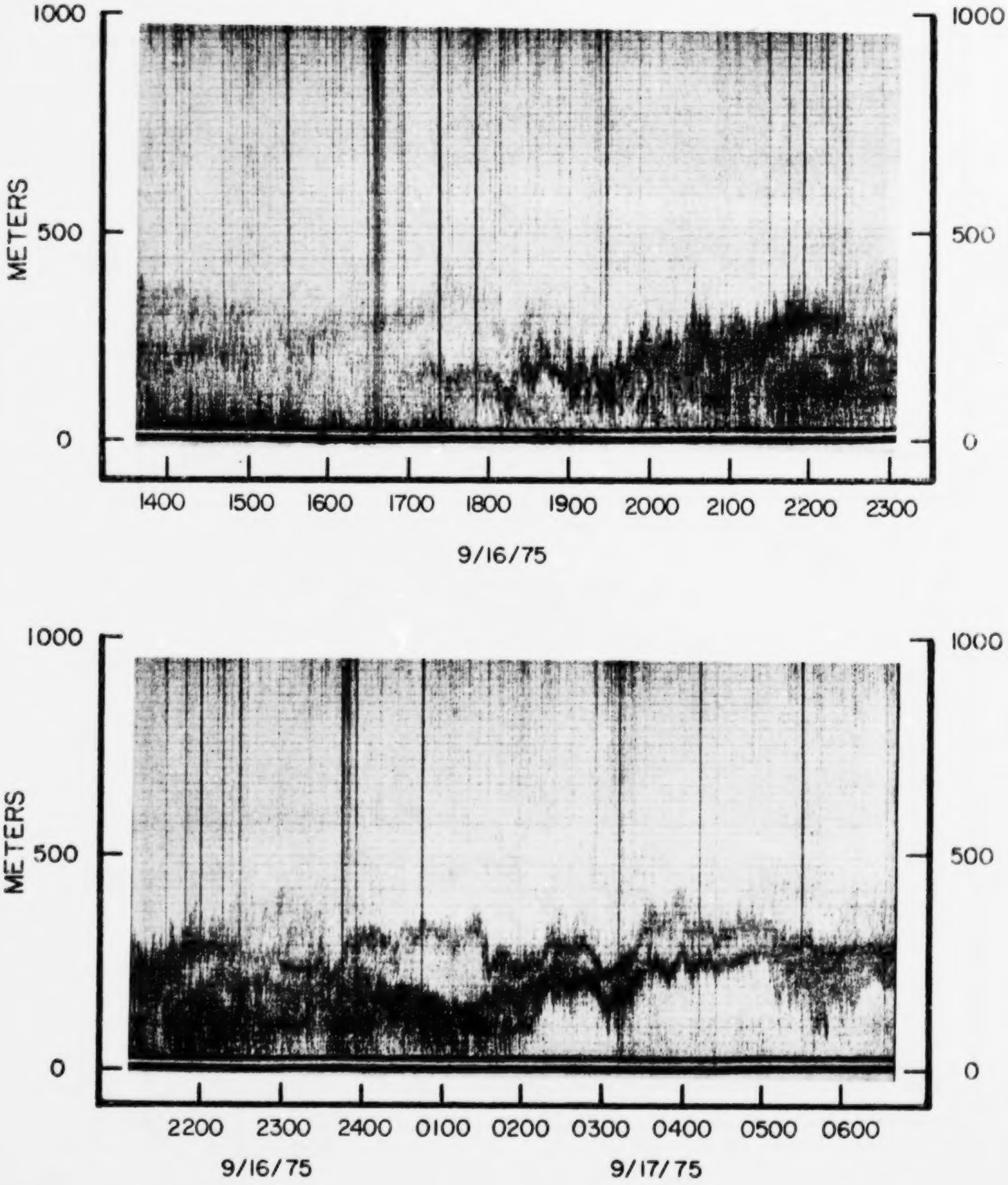


Figure E17. Acoustical Sounder traces recorded on 9/16/75 and 9/17/75.

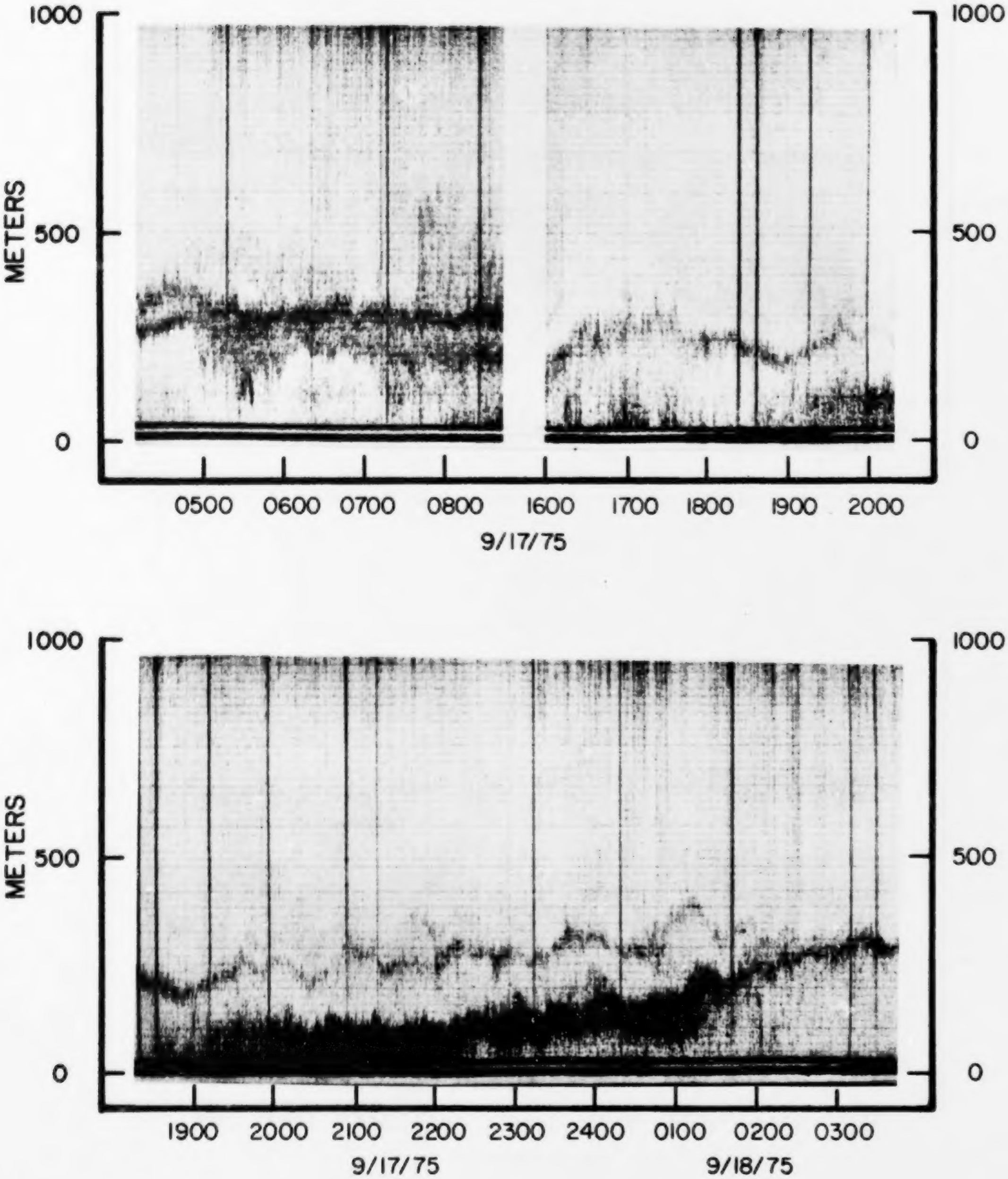


Figure E18. Acoustical Sounder traces recorded on 9/17/75 and 9/18/75.

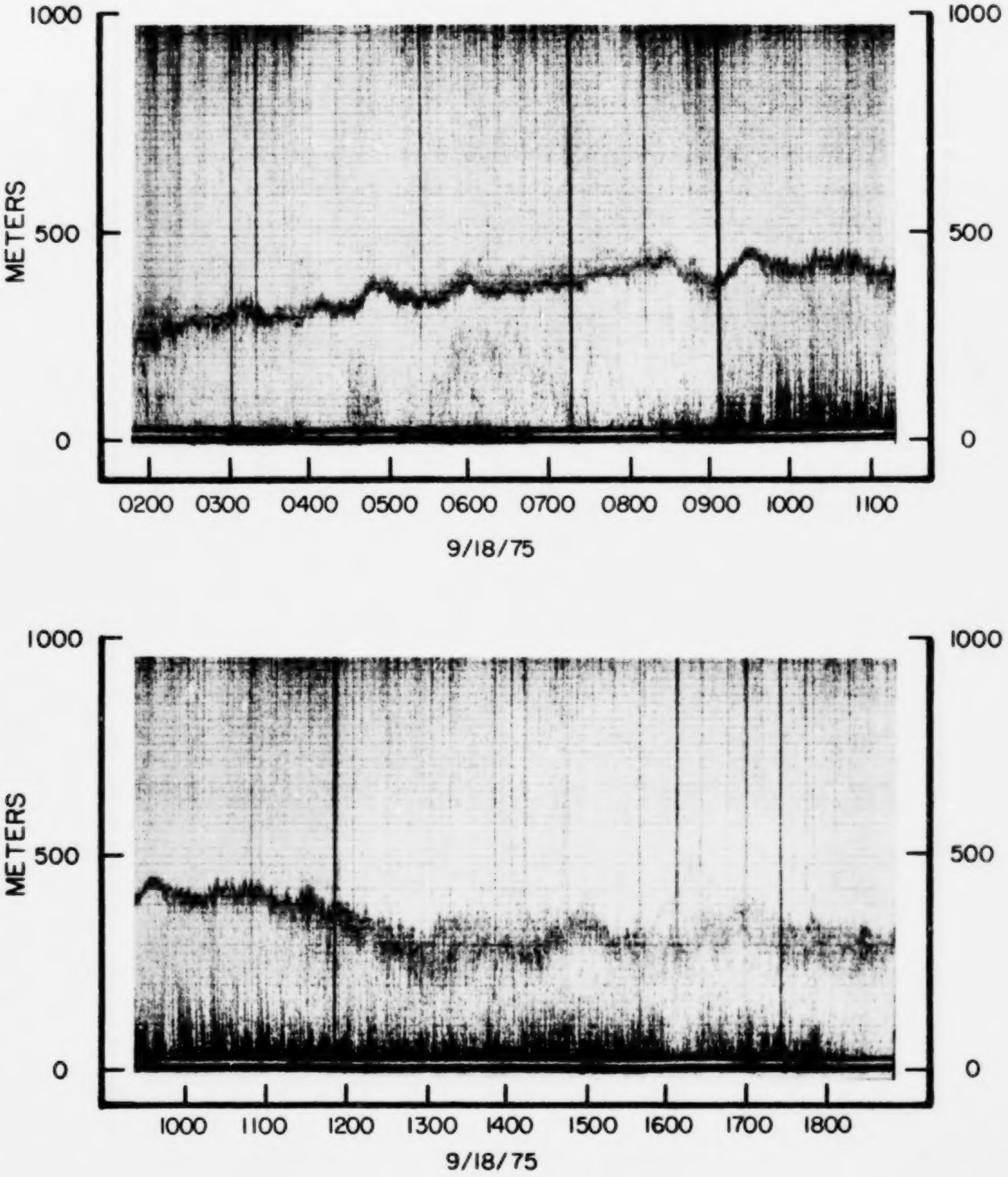
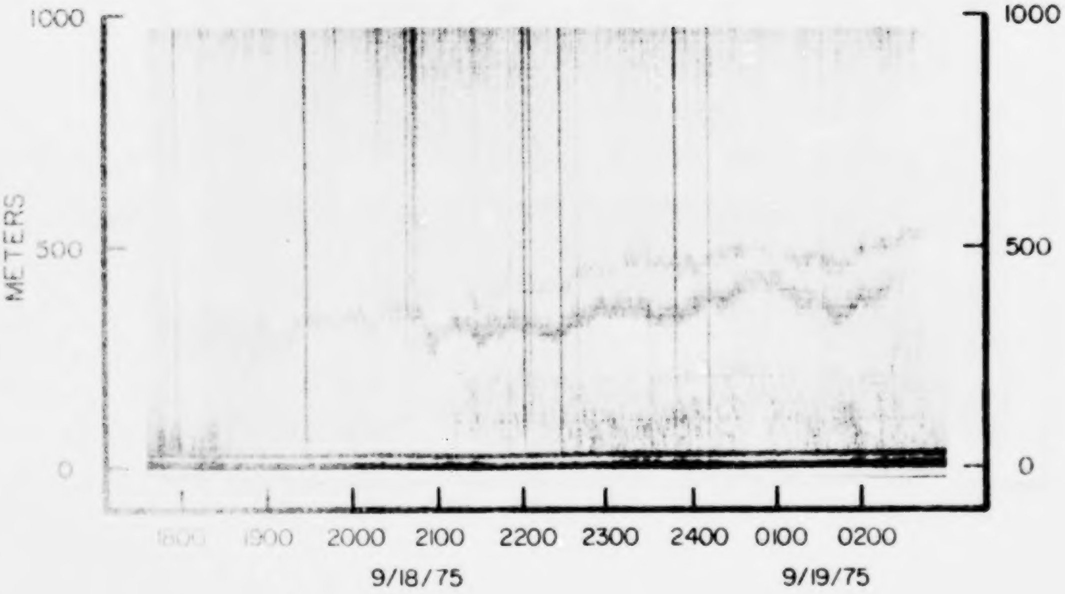


Figure E19. Acoustical Sounder traces recorded on 9/18/75.



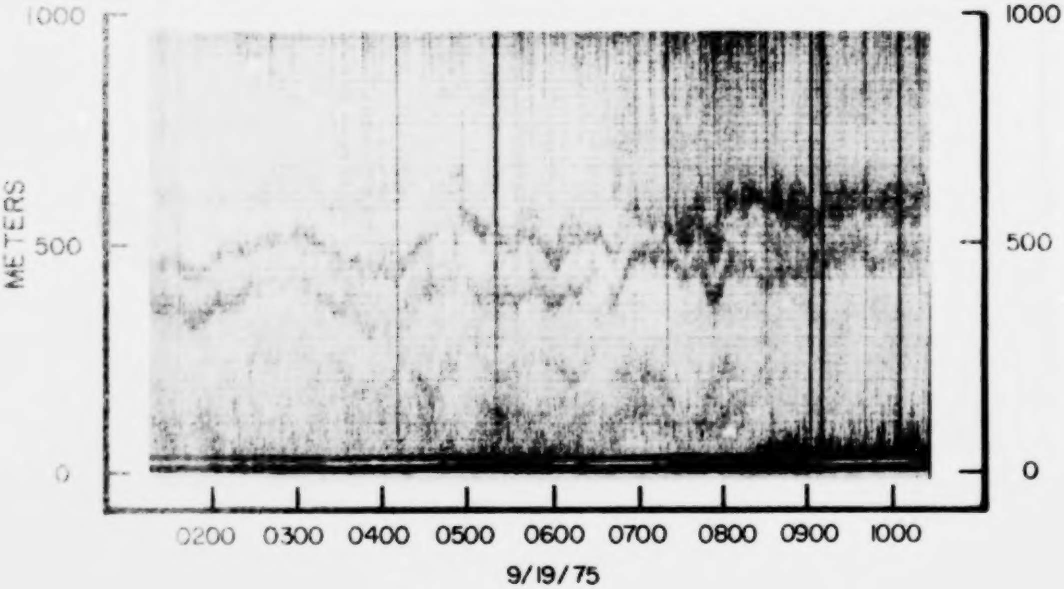


Figure E20. Acoustical Sounder traces recorded on 9/18/75 and 9/19/75.

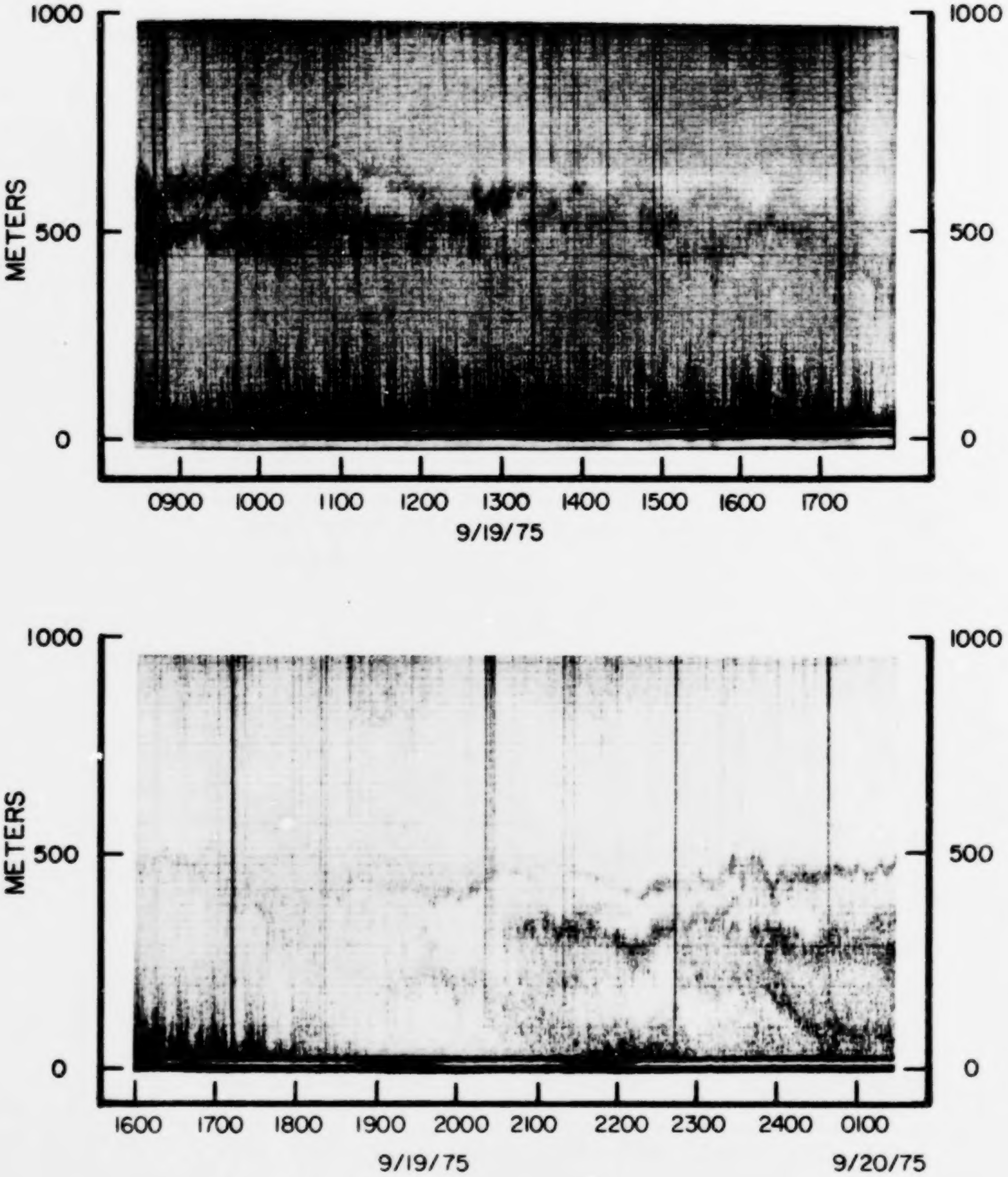


Figure E21. Acoustical Sounder traces recorded on 9/19/75 and 9/20/75.

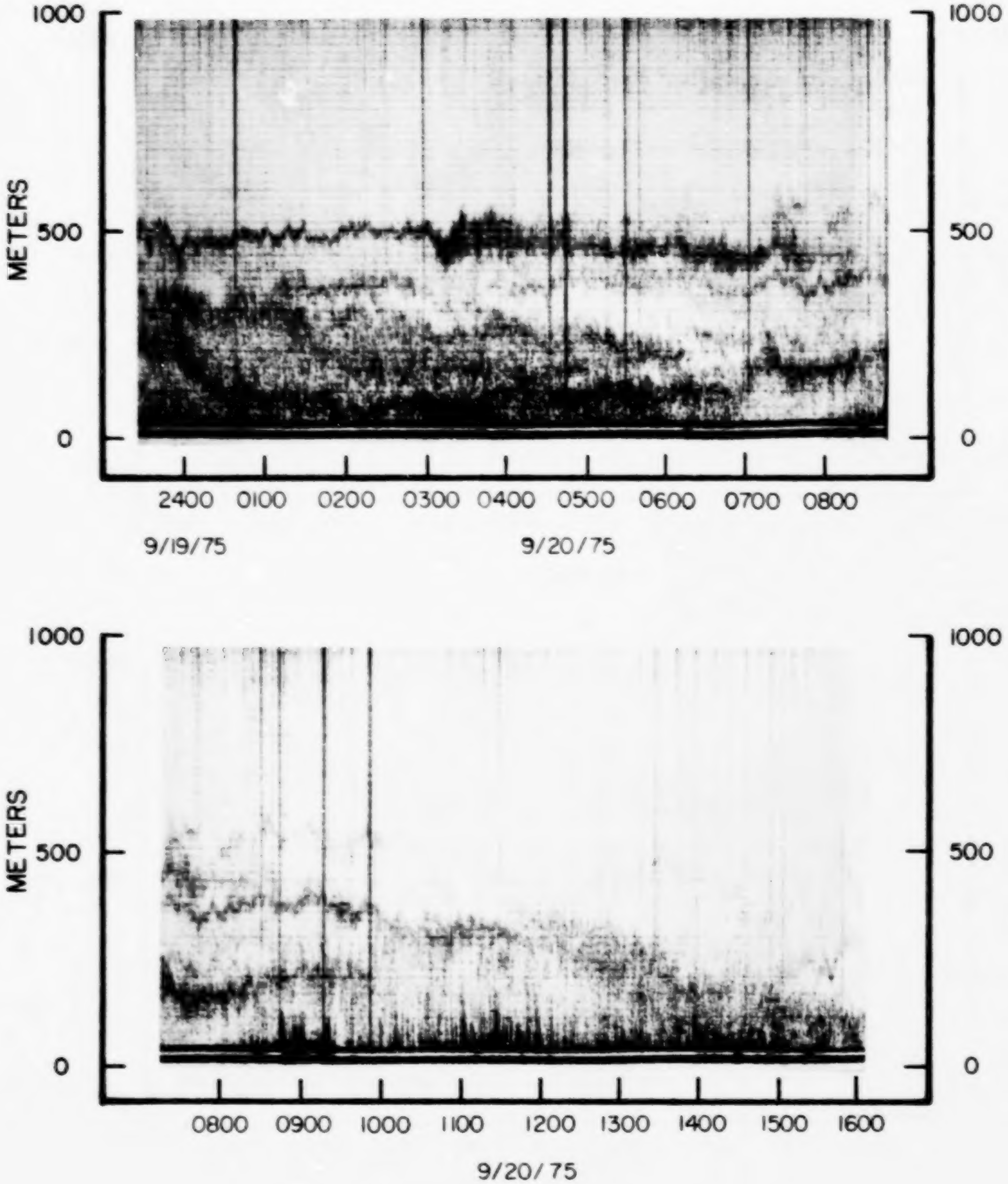


Figure E22. Acoustical Sounder traces recorded on 9/19/75 and 9/20/75.

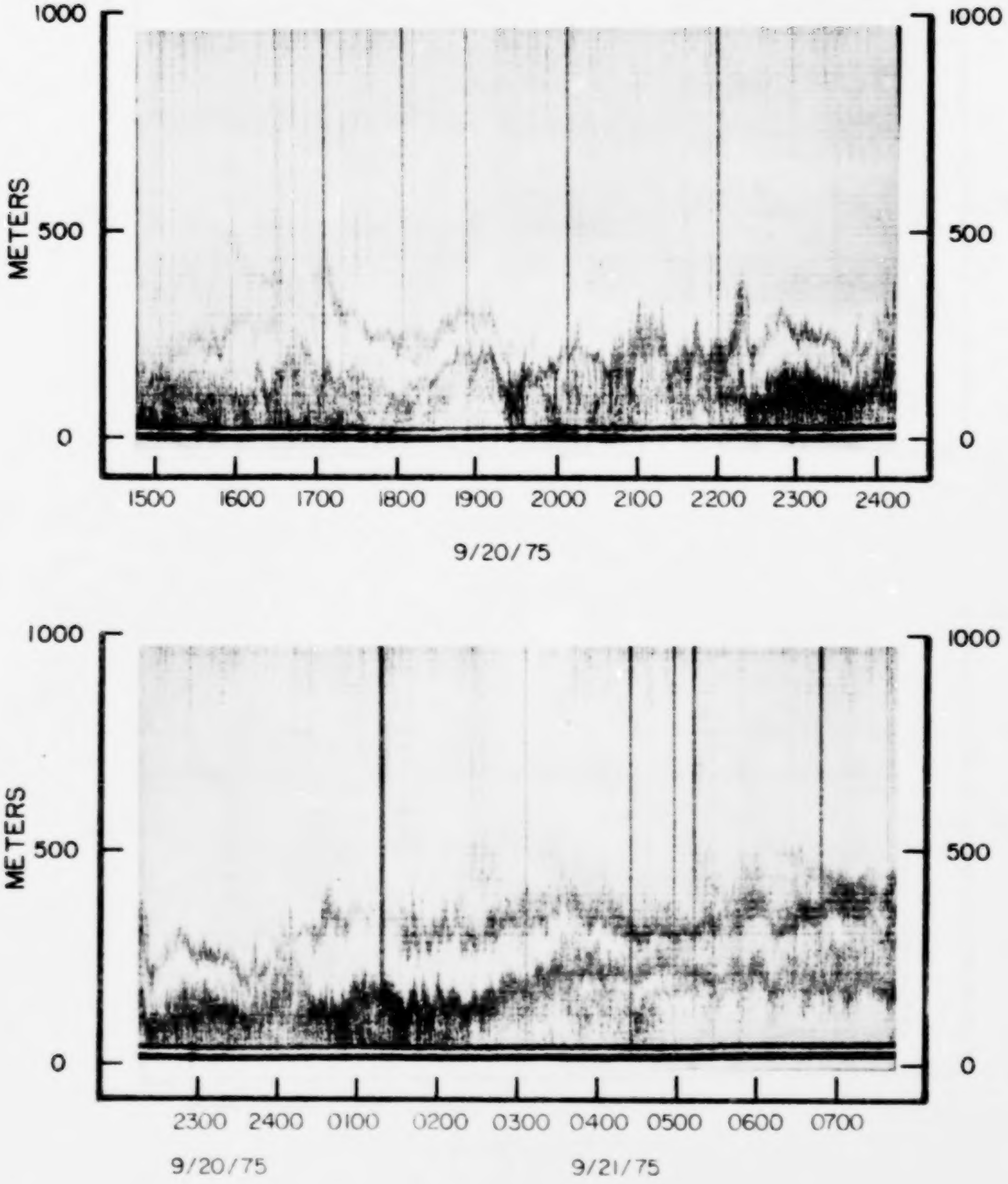


Figure E23. Acoustical Sounder traces recorded on 9/20/75 and 9/21/75.

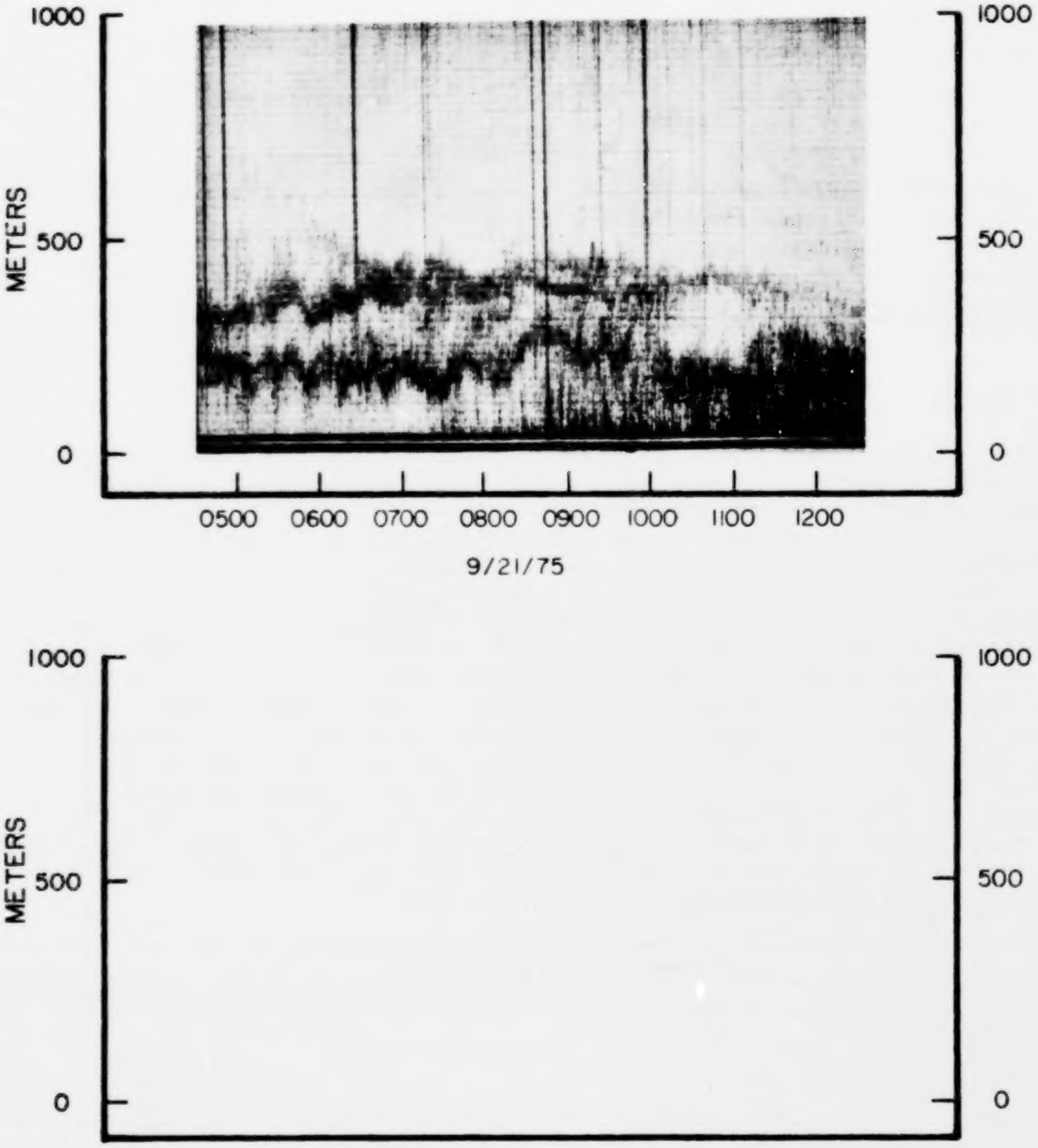


Figure E24. Acoustical Sounder traces recorded on 9/21/75.